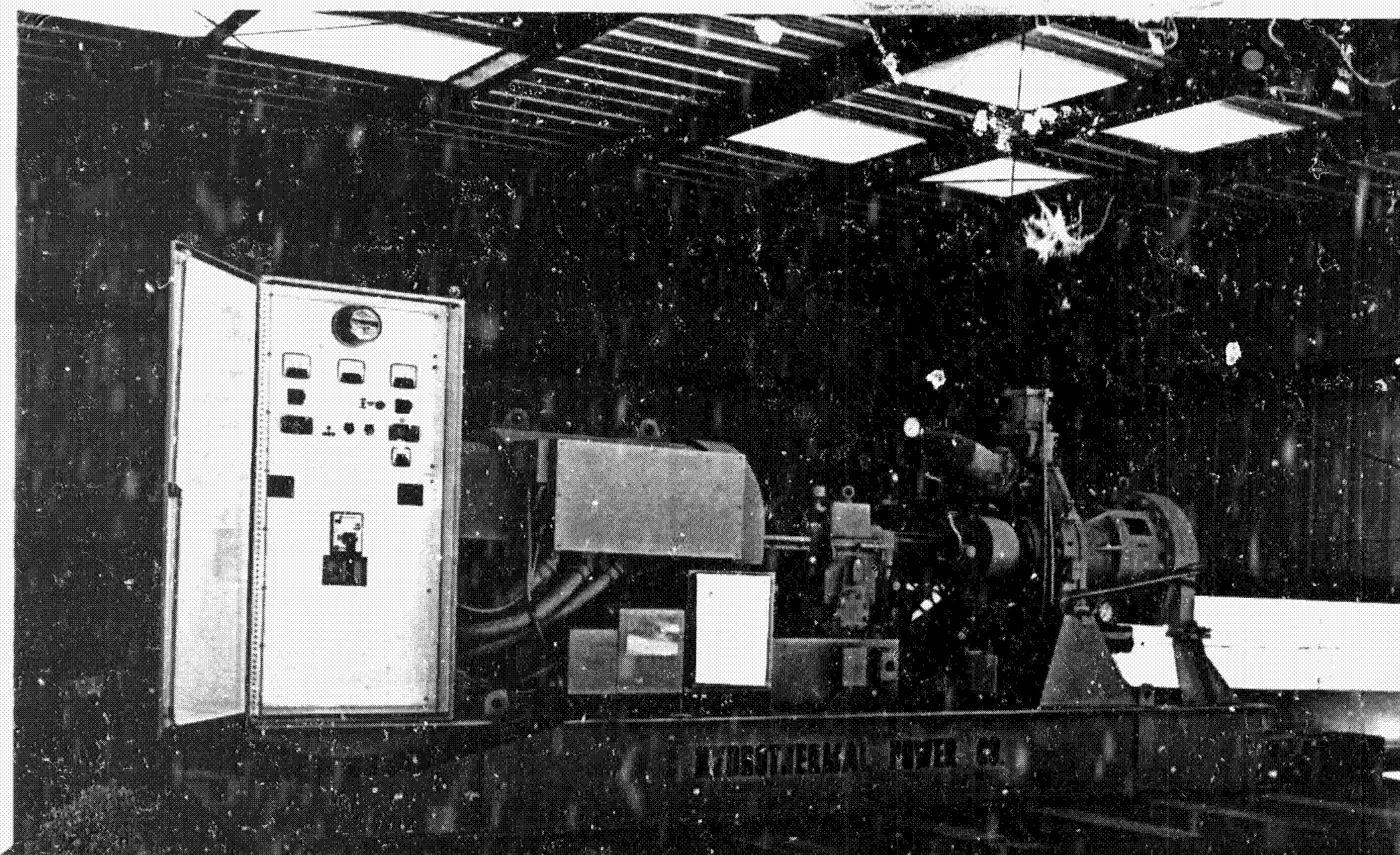

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FINAL REPORT — COSTRUCTION OF A 1 M.W. GEOTHERMAL POWER CONVERSION SYSTEM

FINAL REPORT

DESIGN, FABRICATION, DELIVERY, OPERATION AND MAINTENANCE OF A GEOTHERMAL POWER CONVERSION SYSTEM

THIS WORK WAS PERFORMED FOR THE JET PROPULSION LABORATORY, CALIFORNIA INSTITUTE OF TECHNOLOGY, AND WAS SPONSORED BY THE U.S. DEPARTMENT OF ENERGY THROUGH AN AGREEMENT WITH THE NATIONAL AERONAUTICS AND SPACE ADMINISTRATION.

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TECHNICAL CONTENT STATEMENT

ABSTRACT

This effort involves the design, fabrication, delivery, operation and maintenance of an HPC 1250 KVA geothermal power conversion system using a helical screw expander as the prime mover. The delivery of the power conversion system was made to the Jet Propulsion Laboratory for evaluation and demonstration with geothermal energy consisting of hot, untreated, corrosive scale-forming brines and/or vapors, including the total flow from geothermal wells of such brines and/or vapors.

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SUMMARY

This effort relates to the design, fabrication, delivery, operation and maintenance of a Hydrothermal Power Co., Ltd. (HPC) 1250 KVA Geothermal Power Conversion System, suitably adapted by HPC for testing and evaluation by the Jet Propulsion Laboratory, California Institute of Technology (JPL).

The system was designed, engineered, and patterned after a 62.5 KVA Power Conversion System previously developed and successfully tested by HPC. The design incorporated Background Patents, Know-how, and Proprietory Rights previously developed and owned by Roger Sprankle and HPC. HPC staff and personnel participated in a preliminary system design review held at JPL covering the 1250 KVA Geothermal Power Conversion System.

The Power Conversion System fabrication included the planning of a fabrication sequence starting with the early issuance of purchase orders for long lead time items and concluding with satisfactory acceptance testing by JPL. The issuance of purchase orders followed competitive bidding. Fabrication included: (1) securing of a Vibration and Torsional Analysis; (2) establishment of a Quality Assurance Program; and (3) the development of a Property Control Procedure, acceptable to the U.S. Government.

To assist in the evaluation process, Calibration and Performance data for both the Speed Reducer and Alternator were obtained.

Copies of the manufacturers' manuals or instructions for each major assembly or sub-assembly were obtained in so far as available.

HPC also provided engineering services to JPL for the purpose of: (1) planning for support and interface equipment to be provided by JPL to be used in testing and evaluation; (2) the selection of a geothermal test site suitable for performance evaluation; and (3) the development of detailed plans for site preparation and performance evaluation of the Power System.

Following fabrication of the Power System, hydrostatic testing of the process piping and prime mover housing was successfully accomplished at the HPC facilities, after which acceptance testing was commenced. During the acceptance testing procedures, four equipment failures were experienced. Acceptance testing was successfully concluded and the System formally delivered on December 4, 1977.

A survey of geothermal well sites was concluded with the selection of well No. 54-3, owned by Phillips Petroleum Co., and located at Roosevelt Hot Springs, near Milford, Utah.

Following on-site inspection of the well and test facilities at Roosevelt Hot Springs, a pre-engineered metal "Butler Building" was ordered, and the Power Conversion System was shipped to Utah. The Power System was then installed and assistance given to the JPL Principal Investigator, Dr. Richard A. McKay, covering details of the testing and evaluation. The operation of the Power System in Utah for the purposes of testing and evaluation by JPL was concluded on November 14, 1979. The Power System and related support and test equipment was shipped to Cerro Prieto, Mexico, on December 1, 1979.

INTRODUCTION

The exploitation of Geothermal Energy is included among the efforts of the U.S. Government to resolve the critical energy needs of its citizens. Geothermal Energy is known to exist in the form of dry-steam which is rare and easily developed. However, Geothermal Energy exists more abundantly in the form of hot mineralized water wells. Until the development of the Helical Screw Expander, exploitation of hot water resources had been seriously hampered because no suitable prime mover was available for use with the fluids from these wells. It has been necessary to produce a vapor to drive a turbine, either by flashing part of the brine to steam, as is done at Cerro Prieto, Mexico, or by boiling a secondary fluid in a heat exchanger. In the steam flashing process, much energy is lost in the waste hot brine which flows from the steam separators. Although hot mineralized water wells are common, advanced technical development is required to overcome not only the scaling, corrosive, errosive characteristics of the waters, but also the hostile environment in which most of these hot waters are found.

New technology has been developed by Hydrothermal Power Co., Ltd. (HPC) in extensive research resulting in Patents, Know-how, and Proprietory Rights developed in connection with a prototype 62.5 KVA Power System. The prototype HPC Power System utilizes the helical rotory screw expander design as a prime mover driving a conventional 62.5 KVA generator at speeds controlled by a governor. The prototype HPC Power System is portable and intrinsically self-cleaning in the rotor areas. It is capable of using the liquid-vapor mixture as it comes directly from the well. The prototype unit was successfully tested by operating directly on hot, untreated, corrosive scale forming brines and vapors from wells located at: Cerro Prieto, Mexico (M-7) (M-10); East Mesa, near El Centro, California (62-1); and a geothermal well near Niland, California (Sinclair #4).

The HPC prototype 62.5 KVA power system was the first known power generator to use the total flow of hot untreated brine and vapors directly from a geothermal well. The HPC prototype power system disclosed some interesting and useful technology which HPC believed would assist in the early utilization of energy from geothermal brines. The following observations and conclusions were offered in support of this belief. Paragrpahs 2 through 5 of the following were taken from the writings of R. McKay, JPL.

1. The helical screw expander is a pure rotary, positive displacement machine. The positive displacement feature allows the machine to operate effectively over a broad range of geothermal conditions. The pure rotary motion allows operation in a much higher speed range than reciprocating machines allow. Thus, helical rotary screw expanders up to the fifty MW size range are readily feasible and are ideally suited to geothermal applications.

2. As a geothermal prime mover, the HPC helical screw expander is a total flow machine which can expand directly the vapor that is continuously being produced

from the hot saturated liquid as it decreases in pressure during its passage through the expander. (See Appendix E for cutaway view of prime mover.) The effect is that of an infinite series of stages of steam flashers, all within the prime mover. Thus, the mass flow of vapor increases continuously as the pressure drops throughout the expansion process and the total fluid is carried all the way to the lowest expansion pressure. The process approximates an isentropic expansion from the saturated liquid line for the total flow. The geothermal fluid flows through an internal nozzle control valve and at high velocity enters the high pressure pockets formed by the meshed rotors, the rotor case bore surfaces, and the case end face. As the rotors turn, the pocket elongates, splits into a V, and moves away from the inlet port. With continued rotation, the V lenghtens, expanding successively as the point of meshing of the screws appears to retreat axially from the expanding fluid. The expanded fluid at low pressure is then discharged into the exhaust port.

3. Conditions for mineral precipitation from saturated brines within the expander occur for several interrelated reasons, including temperature decrease, pressure decrease, solvent removal, turbulence and the presence of nucleation sites. The internal surfaces of the expander serve as mineral deposition sites. Mineral deposition on these surfaces accomplishes several

beneficial results. The thickness of the mineral layer increases until the rotor-to-rotor and rotor-to-case leakage clearances disappear and the mineralized surfaces are continually lapped; steady state is reached. The loss of leakage clearances results in substantial increase in the efficiency of the expander. This clearance removal mechanism makes possible the use of less expensive fabrication and machining procedures during manufacture, and also makes the expander self-healing in the event that scarring of the case or rotors should occur. Moreover, the mineral layer has been demonstrated to provide excellent protection of the case and rotors against corrosion. This protection provides greater flexibility in the selection of relatively low cost materials of construction. Similarly erosion is minimal, either because the scale layer forms a protective coating or because the fluid velocities within the machine are not high, or both.

4. The lapping process associated with the minerals which are deposited on the machine surfaces within the expander is a source of suspended nuclei for additional mineral deposition and crystallization within the expander. In an experimental investigation of mineral deposition carried out in October, 1971, while operating a prior helical screw expander on Well M-10 at Cerro Prieto, HPC staff observed that mineral deposition occured either almost exclusively within the expander or on the seed particles traveling with the exhaust brine.

After 307 hours of operation, the deposits ranged from 5/32 inc. at the expander exhaust port to 1/64 in. 50 feet downstream. In the absence of the expander, the same well and feedline plugged shut a 12 in. exhaust pipe in approximately 80 hours. This characteristic of mineral precipitation occuring preferentially within the expander, either on the expander surfaces which are self-cleaning, or harmlessly in suspension, is highly beneficial. The tendency to deposit scale downstream appears to be neglible, at least along an isothermal path. This is important, not only for interstaging, but also in waste lines.

5. Essential to high engine efficiency is small leakage past the rotors. This requires small clearances, both rotor-to-rotor and rotor-to-case. The minute clearances brought about by the wet lapping of the mineral deposits in the geothermal expander leads to maximum efficiences in this new unique application.

Three energy conversion concepts -- the Flashed Steam System, the Binary Cycle System, and the Total Flow System -- are present contenders for producing electricity from hot-water geothermal resources. In the Total Flow System, as represented by the HPC Helical Rotary Screw Expander Power System, the hot wellhead product follows an isentropic expansion directly from the wellhead through the prime mover to the exhaust pressure and temperature. The system is thermodynamically the simplest and is theoretically optimum.

The successful operation of the HPC 62.5 KVA prototype system led HPC to the conclusion that the design and construction of a commercial size system was possible. In April of 1973, two engineers from the Jet Propulsion Laboratory toured the geothermal site at Cerro Prieto, Mexico, and observed the 62.5 KVA power plant in operation. They agreed with the conclusions of HPC staff.

A project proposal calling for the construction and evaluation of an HPC designed 1250 KVA Geothermal Power System was prepared by the Jet Propulsion Laboratory in consulation with HPC, and submitted to, and eventually approved by, The National Science Foundation. The project was thereafter preempted by the Energy Research and Development Administration (ERDA) and then by the U.S. Department of Energy, (DOE), Division of Geothermal Energy, present sponsors of the project.

The project plan called for the construction of a modular HPC 1250 KVA Geothermal Power System, incorporating the helical rotory screw expander as the prime mover, to be operated on total flow brine with an evaluation of the power system's mechanical and thermodynamic performance by JPL. An interagency agreement between ERDA and NASA resulted in the authorization of and financing for the project. Dr. Richard A. McKay, proposal author, was assigned to plan, co-ordinate and manage the project as technical manager and principal investigator on behalf of JPL and NASA.

Jet Propulsion Laboratory contracted with HPC for design, fabrication, delivery, operation and maintenance of an HPC 1250 KVA Geothermal Power Conversion System, with testing and evaluation to be carried out by JPL. An impartial mechanical and thermodynamic performance report and evaluation are the responsibility of JPL.

TECHNICAL DISCUSSION

The design and engineering for the 1250 KVA Power Conversion System built during the effort being reported were based upon a prototype 62.5 KVA Power Conversion System previously designed, engineered and constructed by Hydrothermal Power Co., Ltd. (HPC). The design incorporated Background Patents, Know-How and Proprietory Rights previously developed and owned by HPC. Appendix A is a Descriptive Specification of the 1250 KVA Power Conversion System.

The following discussion has been arranged in chronological order for ease of understanding. The time period is from start of plant construction, January 16, 1976, through shipment from the Roosevelt Hot Springs, Utah test site to Cerro Prieto, Mexico, on December 1, 1979.

Immediately following contract execution, various manufacturers were contacted for current quotations covering price and availability for major long-lead time items. Consistent with competitive bidding, "Requests for Quotations," were issued. A copy of the face sheet of the HPC, "Request for Quotation," form is attached as Apendix B.

The planned method of construction of the prime mover housing was changed from casting to fabricating. A meeting at the Cerro Prieto Geothermal Plant was conducted with the CFE Dept. of Geothermal Studies covering their recommended materials of construction. Their recommendations were co-ordinated with material availability from suppliers. Their recommendations also covered materials of construction for the entire plant.

A basic layout of the expander housing was drafted. The layout was detailed into shop drawings soon after rotor details were finalized. Appointments were arranged with shaft seal and bearing manufacturers. Appendix C contains facsimile copies of records of the chemical analysis, mechanical analysis, and non-destructive testing records relative to the rotor forging. Appendix D contains facsimile copies of chemical and mechanical analysis of material used in the prime mover housing. Appendix E shows a cutaway view of the prime mover.

A meeting with a bearing supplier covered the thrust and journal bearings. Their quotation included strain gauges and thermocouples in the thrust bearing pads and thermocouples in the journal bearing babbitt. All main bearings were sized with a unit loading of 150 psi or less. A meeting was held with a shaft seal supplier. Various designs were discussed, including the shaft seal design in the existing HPC 62.5 KVA Power System.

In March, 1976, a meeting was held with JPL personnel covering the electrical interfacing between the power System and Jet Propulsion Laboratory evaluation equipment. All major electrical equipment belonging to the Power System and supplied by HPC was made ready for purchase. Minor details of interfacing were scheduled for accomplishment during assembly. Suggestions concerning the alternator details were made by the JPL technical staff and these details incorporated into the alternator design. Also, the raw data for the vibration and torsional analysis of the main drive train was assembled and made ready for the actual analysis. In addition, the shop layout and supplies were organized and prepared for the delivery of the first raw materials.

In the following three (3) months, details of the prime mover were attended to and prepared for shop drawings. Items covered included the shaft seals, bearings, O-rings, shims and gaskets, bolt size and loading, and the housing fabrication sequence. Items addressed with respect to the entire power plant included the skid pad, protective coatings, minor electrical details, and the governor control response characteristics. Governing of the plant is achieved by c..ntrolling the position of a moveable nozzle component which forms part of the high pressure port of the prime mover. The hydraulic coupling between the governor and the control nozzle is identical to the existing 62.5 KVA power plant linkage, except for a second stage hydraulic amplifier to handle the greater work load of the larger control nozzle component.

In order to assure quality and conformity between purchase orders and pur.:hased parts, an approved Quality Control Procedure was adopted. A record has been maintained of all signi.icant purchased parts. Appendix F sets forth the estabi'-hed Quality Control Procedure and a copy of the form for records maintained.

While construction of the prime mover housing progressed routinely, attention was also direc-ed to the safety shutdown system and engineering data for the lubrication console.

The basic safety shutdown sys-em consists of a gate valve located in the inlet pipeline to the _ ime mover. This gate valve is held open by a double acting cylinder which, on loss of electrical signal, will close the value automatically. Various sensing switches throughout the plant control this electrical signal. In addition the governor control nozzle trips to the closed position on loss of electrical signal due to a fault. The gate valve construction was chosen with the assistance of engineers from Cerro Prieto, Mexico, and contains both design and materials known to be tolerant to corrosive geothermal brines. Appendix B shows material used for gate valve construction.

The requirements to the lubrication system involve the prime mover, speed reducer, and governor system. The prime mover requirements entail the bearings, seals, timing gears, and the heat transfer through the housing. The speed reducer requirements involve the bearings and gears. The governor system requirements include the governor, hydraulic servo, hydraulic amplifier and double acting cylinder. A small requirement is also necessary for the automatic gate stop valve. After these items were defined, and with their requirements known, the lubrication console was sized accordingly and construction started.

The main drive couplings are of the flexible gear type. The high speed coupling is a spacer type gear coupling with a NEMA standard diametric taper hub on the expander side for ease of removal. Both hubs have puller holes. The low speed coupling is an overload type gear coupling. Both of these hubs have puller holes. The puller holes allow the easy removal of the hubs for gear interchange in the speed reducer.

Following design completion of the main drive train couplings, a vibration and torsional analysis of the main drive train was performed. Appendix G contains the vibration and torsional analysis.

Concurrently with the plant construction, assistance was given to JPL in a site selection survey for plant evaluation. Various potential sites were visited in August, October, December, and January, 1977. As part of the site selection survey, a tour was made of the Roosevelt Hot Springs area in Utah, being developed by Phillips Petroleum Co. This site was eventually chosen as having the best potential of fulfilling the needs of the evaluation project. Major factors affecting this choice were the availability of effluent disposal, high wellhead flow and enthalpy, potential continuous operation of the well, and well flow stability.

From January through March, 1977, a major effort was extended to the welding, grinding, machining, and fabrication of the prime mover. The housing midsection advanced through numerous steps, including the surfacing of the end faces, finish welding to the exhaust section, and set-up for boring. The inlet port and nozzle area was organized, prepared for shaping, and shaped for acceptance of the control nozzle component. The housing was aligned and pinned and the midsection finish machined. The inlet port flange and foot pads were welded to the housing and the housing was assembled in preparation for hydrostatic testing. Numerous minor items were fabricated such as special tools for assembly and disassembly of the prime mover, an alignment fixture to position the prime mover on the skid pad, and hydrostatic test pump equipment.

The hydrostatic testing of the prime mover housing involved two regions, the high pressure region and exhaust region. For hydrostatic testing, the high pressure region was isolated from the exhaust region with a bulkhead fixture. On April 7, the mid and low pressure regions were hydrostatically tested to 450 PSIG, following the ASME Boiler and Pressure Vessel Code. On June 29, the high pressure region was hydrostatically tested to 1080 PSIG, following the ASME Boiler and Pressure Vessel Code. A hydrostatic test was also conducted on all onboard inlet piping prior to installation.

Concurrently with hydrostatic testing, numerous other items were completed. Inspection and acceptance testing was made on the speed reducer. Appendix H contains efficiency and performance curves for the speed reducer. The alternator had been tested and inspected earlier. Appendix I contains efficiency and performance curves relating to the alternator.

The prime mover was assembled for an alignment, clearance check, and pinning of mating parts. Rotor machining and hard-facing were completed and the rotors balanced with bearing, seal, and coupling parts attached. Residual imbalance is shown in Appendix J. Hydraulic plumbing was completed for the shaft seals, governor, bearings, and buffer grease system. Installation of electrical switchgear, wiring, and instrumentation was partially completed with calibration of safety stop sensors.

Subsequent to the hydrostatic testing, the assembled prime mover, speed reducer, and alternator were mounted and aligned on the main skid pad. The alternator was mounted first and bolted directly to the skid pad and aligned with studs to the alternator feet. Next, the speed reducer was mounted to the main skid. Alignment was effected by using thermoplastic grout, brass shims and alignment studs to the speed reducer feet. Finally, the prime mover was aligned to the speed reducer in the same fashion. With the main drive train mounted and aligned, the drive couplings were installed and attention directed towards the completion of sub-systems in preparation for dynamic plant testing.

Prior to dynamic testing, planning was done by staff from HPC and JPL and a procedure formulated entitled, "System Test and Acceptance Procedure". The procedure followed by both JPL and HPC staff is set forth in Appendix K.

Dynamic plant testing was scheduled for August 13, 1977. The first half of the month involved preparation for this testing. A faulty overspeed switch was replaced, and a design improvement was made to the governor override solenoid valves involving the hydraulic port location on the governor.

For dynamic testing, compressed air was used as the motive fluid to drive the prime mover. The dynamic testing was terminated early, after a spline drive to the governor sheared, and in the process destroyed much of the governor. The problem was later diagnosed as a tight fitting spline, allowing no radial mis-alignment between the governor input drive and female rotor shaft. Arrangements were made with the governor manufacturer for a repaired governor, and the clearances on the spline coupling were increased to allow for radial run-out.

The dynamic tesing was re-scheduled for September 14. Preparation included general check-out, replacement of a hand pump with an electric drive pump, and adjustments to the response time in the governor hydraulic system. The acceptance testing was not completed due to a seal failure on the male rotor high pressure end seal assembly. Subsequent to inspection and consultation with the seal manufacturer it was concluded that the failure was due to an extreme overpressure in the supply oil to the seals and lack of proper relief valves for that pressure. It is believed that the extreme overpressure was caused by normal seal heating and subsequent fluid expansion within the seal assembly. Relief valves were installed on the supply oil lines to each of the seals. In addition, the male rotor high pressure end seal assembly was re-installed with only 4 of its original 7 seals. This reduced frictional heating.

On October 20, the power plant was again operated on air. After approximately forty (40) minutes of operation and acceptance testing, rotor contact was noticed. The test run was terminated and re-scheduled for the following week after the timing gears were re-set. It is believed that a contributing factor to the rotor contact was housing distortion due to the cooling effect of the air as it expanded across the prime mover.

On October 27, the power plant was again operated on air. The plant was operated for approximately 1 hour, 45 minutes, during which most of the acceptance testing procedure was completed. The testing was again terminated by a failure on the male rotor high pressure end seal assembly. Subsequent investigation revealed inadequate clearances between the stationary and rotating part due to thermal growth. Added clearances were machined into the seals and acceptance testing scheduled for December 4, 1977.

On December 4, acceptance testing was successfully completed after approximately four (4) hours of continuous operation and satisfactory completion of all items covered in the "System Test and Acceptance Procedure".

As specified in the contract, construction of the Power Conversion System was scheduled for 15 months at a cost of $477,791. Actual construction time was 22 months and 19 days at an aproximate cost of $481,000. The schedule variation is attributed essentially to delays in issuance of initial purchase orders and mechanical problems during acceptance testing.

Following successful delivery of the plant, effort was given to: modifications to the plant needed for operation on Phillips Well 54-3; packaging; and site preparation. The modifications to the plant involved the re-design, ordering and installation of electrical switchgear suitable for the re-injection pumps required for this particular test site. The site preparation involved grading, placement of cross timbers onto which the plant was positioned, and site layout for the location of major items such as the data van, load bank, auxiliary power plant, exhaust holding tanks, shop facilities and living quarters. Appendix L contains a schematic of the Utah test site layout.

Prior to shipment of the Power Conversion system, it became evident to Hydrothermal Power Co. that shop facilities and support at the remote Roosevelt Test Site were unavailable for the project needs. To fill this need, HPC constructed a mobile shop trailer. The shop was well equipped with tools to provide a wide range of services such as welding, cutting, grinding, threading, cleaning, and painting. In addition, the shop contained a broad selection of fittings such as valves, tubing, gaskets, and packing materials. The shop trailer proved to be a tremendous asset at the test site.

The Power Conversion System was delivered to the test site on February 1, 1978. The balance of the month was expended in off-loading the system, site preparation for and placing of the exhaust holding tanks, and errecting a protective steel building for the power system. Assistance was given in the planning for the inlet and exhaust piping, placement of the test van and other test facilities.

Prior to running the Power System, a procedure for logging and recording various important plant parameters, such as oil flows, pressures and temperatures was developed. The recording and logging procedure was planned to compliment the testing data to be recorded by the computer system housed in the JPL Data Van. As a part of the logging and recording procedures, forms were prepared suitable for manual logging and subsequent filing. Appendix M is a copy of the logging form. The initial time period for recording was every one-half hour, but was soon changed to one hour intervals as confidence increased in the process and equipment. Items concerning the plant status were also logged in the data van as part of the test data. In addition, periodic recordings were taken of the main drive train vibration level at eight (8) marked locations. A vibration meter was used for this purpose (Sonidet Meter, Cardwell Condenser Corp.). Also spot visual checks were continually made during operation.

The first half of March, 1978, was expended in assisting the Principal Investigator, Dr. Richard McKay, in the completion of the inlet and exhaust piping and data aquisition system. The first run was on March 16. After approximately fifteen (15) minutes running, a governor spline broke. Repairs were made to the governor and the system was again run on March 21. During the balance of the month, the system was run at intervals, being shut down frequently while changes in the inlet piping and inlet piping controls were made under the direction of the Principal Investigator.

Operation and testing at the Utah test site can be broken into two (2) catagories: Power System Operation and Site Process Operation. The Power System involves only the process from the inlet flange to the exhaust flange of the HPC Power System. The Site Process includes everything from the wellhead through the Power System to the disposal well located one and four tenths (1.4) miles from the wellhead.

Initial operation of the Power System involved becoming familiar with the site process and then adjusting the process controls for stable, steady operation; a critical requirement for testing. A significant improvement was made to the site process operation when the wellhead separator level was instrumentated and proper level maintained.

A problem that persisted throughout all the testing involved the inlet piping from the point where the steam and water were mixed to the point where the mixture entered the prime mover. The problem manifested itself in the form of unstable flow and slugging which prevented stable 60 cycle operation, forcing the plant to vary at times ± 2% in frequency. This unstable flow was most noticeable between an inlet quality of 1% and 10% steam. With qualities greater than 10% steam, the higher flow velocities appeared to assist in mixing. Different diameters of inlet piping were tried with some success, in an attempt to prevent unstable and slugging flow. With zero steam quality or all liquid feed, the plant operation was surprisingly smooth and steady. However, under some conditions, where the inlet control valve was partially open, water hammer would occur in the inlet piping.

Concurrently with the effort to improve the unstable inlet flow, efforts were made to improve the governor system performance. Some success was obtained by cutting throttling notches into the spool for the hydraulic amplifier.

Another problem area during plant operation involved silica scale buildup in the waste disposal pump strainers. Part of the pipeline between the waste holding tanks and the pump inlets took advantage of an existing used pipe, previously installed for other purposes by Phillips Petroleum Co. This pipe length continuously shed scale which clogged the strainer to the pumps along with new scale which was continuously precipitating during plant operation. Much of the used pipe was removed with some improvement to this problem. By alternately switching between the duplex pumps, plant operation was maintained with repetitive strainer cleaning as required.

Another problem of a more serious nature involved the prime mover shaft seals. As testing and plant operation progressed, the seal leakage rate continued to increase. On April 23, inspection revealed that the male low pressure seal leakage rate was excessive. Subsequent removal revealed a cracked seal sleeve and serious errosion, with silica scale build-up. The seal assembly was replaced. In the hope of preventing another failure air was injected through pre-existing ports to the high pressure end seals. Pre-existing ports were not available to the low pressure end seals and could not be machined into the housing in the time available. Well shut-in was scheduled for June 1, 1978. The decision was made to continue testing with the recognized risk of another seal failure.

On May 31, 1978, one day before the scheduled termination of the Utah testing, the same shaft seal failed in a catastrophic manner. The seal failure friction welded the seal sleeve to the shaft, ruptured and demolished the seal assembly, bent the shaft, and due to excessive heating, melted the adjacent bearing babbitt.

Repair of the plant began subsequent to the post calibration of the evaluation instrumentation, preservation and storage of process equipment, and well site cleanup. Repair of the power plant was centered around repair and re-designing of the shaft seals and improvemement of other plant aspects for better all around performance.

The fundamental design change to the shaft seals involved the addition of a fresh water flow across the seal area exposed to the brine process. This fresh water acts as a shield, or buffer, preventing mineral build-up in the seal assemblies.

To accomodate the new seal design, the safety shutdown system was changed. The change involved the installation of flow switches to each seal flush water line. The change also involved differential pressure switches and gauges installed on the oil/flush water system on each seal assembly. These switches are all wired in series with the existing shaft seal pressure relay. In addition, to handle the additional power requirements of the 24 VDC system, the batteries and battery charger were changed to a larger size.

At the Utah test site, there was no source of fresh water for use across the shaft seals. For the continued Utah testing, the most readily available source of flush water was determined to be steam condensate. The equipment involved is a steam/exhaust brine heat exchanger located in the exhaust holding tanks and then a condensate/air heat exchanger to supply a holding tank with condensate at a temperature $\leq$ 160°F. The holding tank is used to supply a metering pump which feeds each seal assembly.

During the 1978 spring testing in Utah, the power plant experienced an abrupt load loss of more than 500 KW with subsequent overspeed and automatic shutdown. Proper governor design should be responsive enough to allow full load changes without overspeed or underspeed shutdown. A design improvement of the plant involved a custom built hydraulic amplifier and increasing the hydraulic oil supply for quicker governor response and greater work rating.

Also during the 1978 testing, water hammer was experienced at some control value positions with all liquid inlet feed. The inlet port configuration was subsequently changed to eliminate this problem.

In addition, during the spring testing, it was determined that there was one major source of noise, the alternator cooling fan. In an attempt to attenuate the noise, a quieter fan was installed, shrouded and lined with a sound absorbent material, and ducted away from direct ear contact.

With resumption of well flow by Phillips Petroleum Co., in the spring of 1979, and mid July completion of the plant repair, efforts were directed to the evaluation equipment re-installation, calibration, and general test site preparation. Equipment calibration and site preparations were hindered somewhat by a well blow-out in June 1979, which deposited salts and scale over the entire test site, causing numerous electrical problems.

Checkout of the fresh water system revealed that the steam condensate contained large amounts of iron carbonate, which precipitated probably as siderite. Various methods were attempted to solve this problem. The solution involved changing the design, to first aerate and mix the hot condensate with bentonite and then hold the mixture in a large tank where the bentonite and newly formed iron oxide would settle out. The resulting water was then filtered to 25 microns and fed to the seal metering pump.

Plant operation for testing commenced on August 29, 1979. As testing continued, it became apparent that naturally formed mineral depositions would not close the clearances internal to the prime mover. The rate of deposition was too slow to close these clearances in the time allowed for testing. Recognizing the importance of internal clearances to prime mover performance, an attempt was made to chemically force mineral deposition to occur at an accelerated rate.

The method used to force mineral deposition to occur involved the injection of a calcium chloride solution directly upstream of the prime mover inlet. The necessary equipment involved mixing tanks for the solution, a metering pump, and an injection line to the prime mover inlet. Various combinations of concentration and flow rates were attempted with some success. However, the resulting calcium carbonate deposition that did occur deposited preferentially in some areas and not others, and continally broke off in large scales. The attempt to force mineral deposition to occur was subsequently terminated and attention given to other aspects of the evaluation.

One incident did occur, however, that demonstrated the need for a jacking motor to slowly rotate the plant immediately after stopping and before starting. Upon stopping the plant after a test run, during which a particularly concentrated solution was injected, the rotors became locked as the housing was allowed to cool to ambient temperatures. In order to free the rotors, it was necessary to block the exhaust port and fill the housing with a mild solution of hydrochloric acid and metal pickling inhibitor. After approximately 24 hours of soaking, the rotors became free and testing was continued. A jacking motor has subsequently been installed and appears to have solved this problem.

During continued testing, water build-up was noticed in the main lube oil reservoir. Inspection revealed that flush water was migrating back across the shaft seals into the bearing areas, and to the oil reservoir at a rate of approximately 100 cc/min. This leakage was recognized as a seal short-coming and that the water would have to be periodically removed at the reservoir. For the short term and continuation of testing, bleed steam was used to dry the reservoir during periods of plant shut down. For the longer term a water/oil separating centrifuge was ordered for continuous water removal.

Concurrently, with the test activities in Utah, many visitors observed the plant in operation. During one visit, a group of foreigners, some of whom were involved in geothermal activities in their respective countries, toured the test site. They were impressed with the plant operation and test activities. Their interest led to an International Energy Agency (IEA) agreement, whereby the Power System and support test equipment would travel abroad for demonstration purposes. First on the demonstration schedule is Mexico, where the plant would be operated in the geothermal field at Cerro Prieto.

Utah plant operation and testing was terminated on November 14, 1979. Post calibration, packing, and site clean-up followed, with loading and shipment to Cerro Prieto, Mexico, on December 1, 1979.

The support activities in Utah involved a time period of 24 months from plant delivery on December 4, 1977, through shipment to Mexico on December 1, 1979. Total cost for Hydrothermal Power Co. efforts during this time period was $530,927.

CONCLUSIONS

As a result of the reported effort, we conclude:

1. Problems associated with the initial plant operation are considered incidental and should be viewed as a normal debugging process for new equipment.
2. Varied geothermal well production characteristics put a large demand on the governor system. Control needs to be maintained over a wide range of inlet pressures, flows, and electrical loads. Design improvements to the governor system should satisfy these control needs.
3. That substantially all of the conclusions from the testing of the 62.5 KVA Prototype Power System are confirmed. In particular, the following conclusions were verified.
   - A. The helical screw expander is a useful, efficient, total flow prime mover;
   - B. The scaling or mineral deposits reduces leakage, between rotor-to-rotor and rotor-to-case, resulting in a substantial increase in machine efficiency.
4. That internal inspection of the prime mover has revealed nothing to prevent long term maintenance free operation.
5. The nature of the equipment, including the fault and safety shut down system, points to a Power System capable of extended periods of continuous, unattended operation.

6. That a Geothermal Power System could be built from a standard set of materials, adaptable to a large variety of geothermal wells and fields, and developing mechanical efficiencies greater than 70%.
7. That adoption of the recommended modifications would enhance the efficiency and overall attractiveness of the HPC Power System to the Geothermal Industry.
8. Test results have shown that the power conversion system does have an application for power recovery from geothermal brines having an extremely broad range of qualities.
9. The prime mover can be characterized as having a weight to power ratio somewhere between turbines and reciprocating prime movers. For example, with an installed prime mover weight of 100 tons, a diesel would produce 12 MW, a helical screw 30 MW, and a steam turbine 200 MW. This will limit the single shaft power output from a helical screw to about 50 MW utilizing existing heavy industry. This size may be increased by utilizing fabricated hollow rotors. An attractive size appears to be approximately 5 MW where the entire power plant can still be maintained easily transportable on skids and located near the wellhead.

RECOMMENDATIONS

The following recommendations are based upon operating experience. If adopted, they should result in reduced maintenance and simpler future operation.

We recommend:

1. a H_2S removal system be installed in all electrical enclosures;
2. a longer and wider main skid-pad for easier equipment access for servicing and maintenance;
3. that the safety shut-down electrical system be isolated in its own enclosure;
4. that the hydraulic actuator to the automatic stop-gate valve be located in a vertical position;
5. that the hydraulic actuator of the automatic stop-gate valve have an adjustable stroke cushion to reduce mechanical stresses on the main drive train during fault shut-down;
6. that the inlet pipe to the prime mover be welded to the main skid pad to reduce stresses to the prime mover feet, which could lead to misalignment;
7. that provisions be built into the lube oil console for additional cooling capacity when the plant is operated in hot desert environments;
8. that additional inspection ports be built into the prime mover housing;

9. improvements be made to the governor control system to allow stable plant operation at various inlet pressures and electrical loads;

10. a larger lube oil reservoir capacity to accommodate oil loss due to nominal shaft seal leakage;

11. that the manual start hand pump be changed to electrical drive;

12. that an event recording system be installed to monitor the plant and record the failure sequence in a fault shutdown;

13. that additional testing be done at different speeds, and with various field parameters;

14. that an HPC Power Conversion System, with a nominal capacity of 5 MW be constructed, incorporating the above design changes.

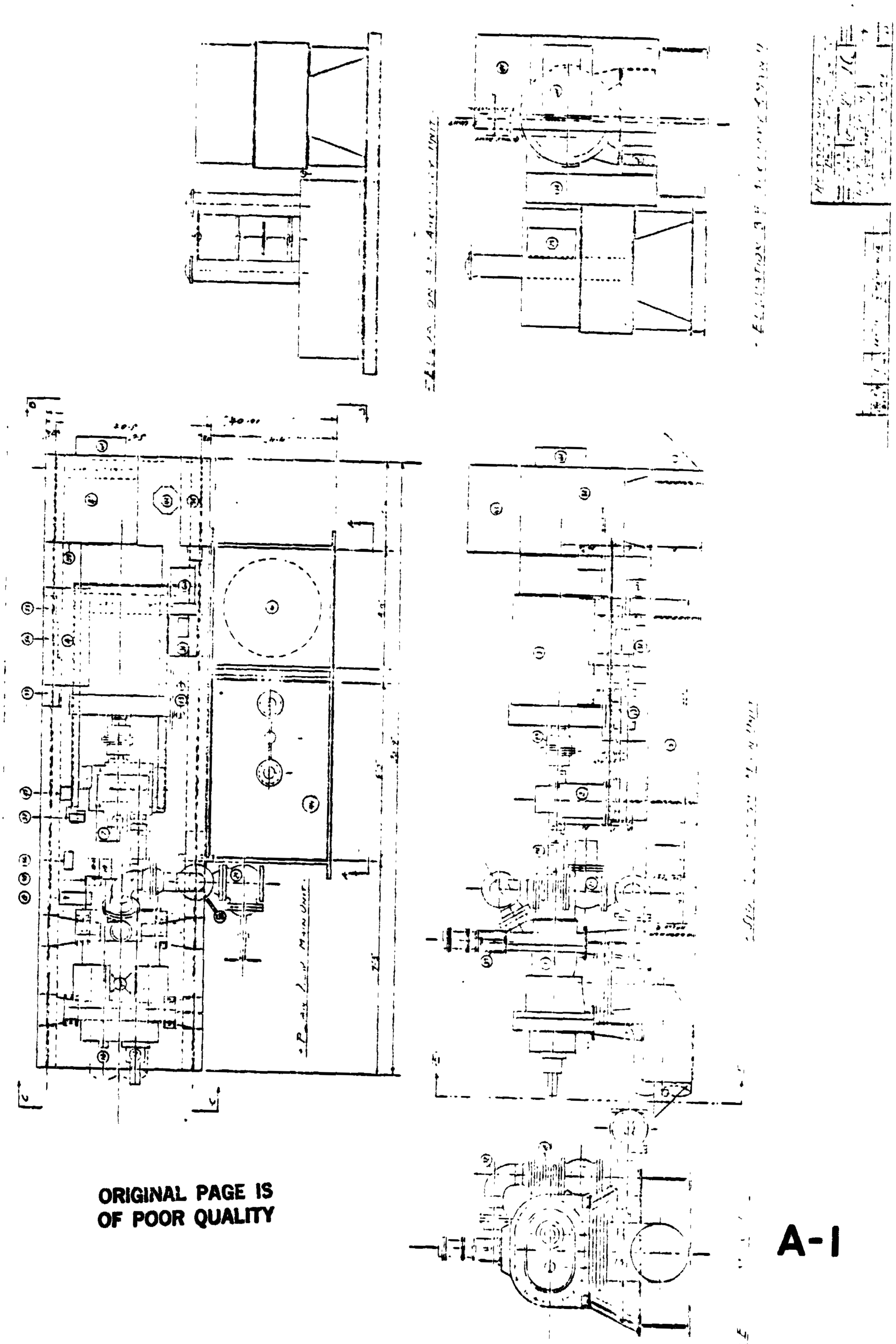
NEW TECHNOLOGY

Prior to the issuance of the subject contract, Hydrothermal Power Co., Ltd. (HPC), had developed New Technology through extensive research, resulting in patents, know-how, and proprietory rights. The research culminated in the successful operation of a prototype 62.5 KVA Power System.

Following the execution of the subject contract, HPC petitioned the U.S. Department of Energy for and received an "Advance Waiver" on New Technology developed during the performance of the contract.

No reportable items of New Technology were identified or developed during the fulfillment of the contract terms.

APPENDICES



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A-1

DESCRIPTIVE SPECIFICATION

for

GEOTHERMAL POWER CONVERSION SYSTEM

supplied by

HYDROTHERMAL POWER CO., LTD.

Pasadena, California

May 9, 1980

The Geothermal Power Conversion System consists of a Lysholm type expander with sixteen and one-half (16.5) inch diameter rotors, a speed reducer and an alternator, complete with all necessary auxiliary equipment and accessories required for use as a geothermal wellhead electrical generating plant. The drive train is a skid mounted, factory assembled unit, susceptible of transport without dismantlement. Heavy tarpaulins are provided for protection of the System during shipment or site storage. The Contractor's predictions of System performance are set forth in Appendices 1 and 2 herewith. The System includes the following assemblies, sub-assemblies and components:

I

Main Drive Train

The main drive train is mounted and aligned on a structural steel base pad or frame. The basic envelope is 6 ft. in width, 8 ft. 1" in height, and 25 ft. in length; the weight is approximately 25,000 lbs. The main drive train is exposed for ease of interfacing with process piping, lubrication oil console, and electrical switchgear. The equipment is designed for outdoor, unattended operation for extended periods. The main drive train consists of the following sub-assemblies:

(Prime Mover)

The prime mover is a Lysholm-type machine designed for operation as a high enthalpy brine expander having the following features:

1. A fabricated steel housing with porting to provide for a variable volume ratio. The housing incorporates a gate-type governing valve that controls this variable volume ratio. The inlet port is an 8-inch, 300 lb., ANSI raised-face flange. The maximum allowable operating condition is 625 psig at 500° F.

2. The low-pressure end is of stainless steel with a 24-inch, 150 lb., ANSI raised-faced flange.

3. The shaft seal assemblies consist of a combination of segmented carbon seals, floating ring seals, and labrinth seals. Oil is maintained behind the segmented carbon seals at a pressure slightly higher than the flush water pressure to prevent water intrusion into the oil system.

4. Radial bearings are pressure-lubricated, tilt-pad type sized for moderate to low specific bearing pressure. Thrust bearings are large, sturdy, self-equalizing type of conservative design for long life. One hundred ohm platinum resistance temperature detectors are provided on all bearings.

5. Two 1 1/4-inch, threaded, plugged, inspection holes are provided in the rotor bores with provisions for measuring rotor wear.

6. Rotors are machined from solid, one-piece forgings to provide the maximum practical bending strength.

7. Rotor construction is suitable for 100 psi pressure differentials at rotor speeds up to 5,000 RPM.

8. Hard-surfaced rotor tips and end faces are provided.

9. A jacking motor is provided to slowly rotate the prime mover during periods of startup and shutdown.

The prime mover housing is hydrostatically tested according to the <u>ASME Boiler and Pressure Vessel Code</u>. The inlet and high pressure regions are tested to meet or exceed a 300 lb. ANSI rating. The exhaust and low pressure regions are tested to meet or exceed a 150 lb. ANSI rating.

(Speed Reducer)

A suitable speed reducer is provided and is flexibly coupled to the prime mover and to the alternator. The speed reducer is a parallel shaft horizontal offset design having sleeve type bearings. Lubrication is provided from the main lubrication console. The high and low speed couplings are self-aligning gear type with sealed grease lubrication. The low speed coupling is of the shear-pin type. The couplings are designed to operate for 20,000 hours before recommended disassembly for an alignment check and re-lubrication. The speed reducer is generously sized for an extended life of greater than ten years before overhaul. Gear sets for three gear ratios, 5000/1800, 4000/1800 and 3000/1800 rpm (approx.) are supplied with the gearbox.

(Alternator)

The alternator is a continuous duty 1000 KW, 1250 KVA, 0.8 p.f., 1800 rpm., 3 phase, 60 HZ, 480/277 volt, 4 lead, 2 bearing, drip proof, enclosed machine suitable for operation in a desert environment, and having a directly connected brushless exciter and a solid state voltage regulator. The alternator bearings are of the antifriction type with double shields and are lubricated at the factory. The alternator bearing is of a design capable of ten years of continuous operation. Two 100 ohm platinum resistance temperature detectors are installed in each phase of the windings to make possible a continuous indication of alternator temperature. A 100 ohm platinum resistance temperature detector is installed on each bearing. To reduce noise, the cooling fan is ducted and shrouded away from direct ear contact.

II

Oil System

The oil system provides bearing lubrication as well as cooling for the prime mover and the speed reducer. It also provides oil for the shaft seal needs and the hydraulic needs for the speed governor and safety shutoff mechanisms. The oil system also includes a heat exchanger and other provisions necessary to maintain the prime mover and the speed reducer at proper operating temperatures by transfer of heat from the oil to the surrounding atmosphere. A fully automatic greasing system is provided for the lubrication of all critical surfaces or bearings within the brine inlet and governor control valve. The oil system includes the following subassemblies and components:

(Lubrication Console)

1. 300-gallon reservoir with sight gauge, breather, and fill cap

2. Duplex filter and transfer valve

3. Forced draft oil-to-air heat exchanger

4. Oil pump directly connected to speed reducer at 1800 rpm

5. All associated piping, temperature and pressure regulators, gauges, and switches

(Shaft Seals)

1. Booster oil pump, filter, accumulator and regulators to shaft seals

2. A flush water pump, duplex filter with transfer valve, and flow meters to feed one GPM of suitable flush water to each shaft seal

3. A water-oil centrifuge to remove water from the seal oil discharge

(Auxiliary Functions)

1. Sufficient oil capacity and accessories are provided to assure proper operation of the governor and its hydraulic amplifier

2. Sufficient oil capacity and accessories including an accumulator are provided for hydraulic operation of the automatic gate shutoff valve.

III

System Control
(Speed Governor System)

The governor system has the following features and characteristics:

1. The governor is a mechanical flyball-type, flexible spline connected to the female rotor of the prime mover.

2. The governor output is amplified through a hydraulic servo mechanism for operation of the governing valve located in the prime mover inlet port.

3. There is a means for adjustment of the governor with provision for remote control from the electrical control box.

4. The governor control mechanism provides means for either isochronous control or droop control at the election of the operator. The accuracy of control in either case is within plus or minus one quarter (1/4) of 1% of the speed set or selected by the operator.

(Automatic Gate Shutoff Valve)

The automatic gate shutoff valve is wired for automatic fail-safe operation wheneve there is a dropout of the electrical signal required to hold it open. The generator output breaker trips open also with a dropout of the electrical signal due to underspeed.

Provisions are made for actuation of the automatic shutoff valve in consequence of any one or more of the following conditions, any one of which will trip and fully close the automatic gate shutoff value within fifteen (15) seconds:

1. Underspeed
2. Oil supply overtemperature
3. Oil supply underpressure
4. Shaft seal low differential pressure
5. Shaft seal low flush water flow
6. Excessive vibration
7. Actuation of manual stop switch

Provisions are also made for actuation of the automatic shutoff valve in consequence of any one or more of the following conditions, any one of which will trip and fully close the automatic stop gate valve within one (1) second:

1. Overspeed
2. Actuation of manual emergency stop switch.

Relays are provided for remote actuation of both the stop and emergency stop switches.

IV

Electrical Systems

The Geothermal Power Conversion System is designed for starting without any external electrical power source. Batteries are provided to energize the safety shutoff circuit during startup and during normal operation. During operation, all necessary electrical energy, including that for battery charging, is provided by the System itself. All of the electrical lines, connections and contacts are protected from the corrosive salts and gases prevalent in geothermal environments. Protection for all instrumentation and signal wires is provided by conduit, gutter or tray as appropriate for the protection and isolation of such circuits within the perimeter of the Geothermal Power Conversion System. The electrical system includes the following subassemblies and components:

(Alternator Control and Protection)

The alternator is provided with all necessary or required protective and control devices requisite for safe operation. Accordingly, an output circuit breaker complete with solid state protective devices for circuit fault, ground fault and thermal overload conditions is provided for the main load. The output circuit breaker has a 120V AC shunt trip coil. In addition, a 400 amp., 480 V., 3 phase breaker panel is provided for possible power needs at the geothermal plant site. A separate 120 volt output breaker is provided for all inhouse usage.

The alternator is provided with a control box or console having provisions for the measurement of alternator frequency, voltage, current, power output, and kilowatt hours. A current transducer and a power transducer each provide 4 to 20 MA output. Indicating meters are provided within the control box. Means are also provided there for the convenient connection for external recording of amperage and voltage. The control box also contains an elapsed time meter, necessary relays and timers, as well as the voltage regulator and a remote governor control switch. A 10 KVA single-phase transformer with 110/240 volt output together with output circuit breakers for the control of all electrical energy (station power) used for operation of the System is also provided. The arrangement of the control box panel is generally in accord with JPL Drawing No. SE/60-0 that appears in the JPL ELECTRICAL STANDARDS published in June 1975 by the JPL Facilities and Engineering Construction Office.

(Remote Monitoring)

A terminal box containing a terminal strip is provided to facilitate the remote monitoring of the following:

1. Alarm and sensor contacts giving indications of improper speeds, pressures, temperatures or vibrations

2. Remote circuit breaker trip mechanism

3. Station power (120/240 volt)

4. Temperature sensors

5. Bearing load sensors

6. Amperage transducer

7. KW transducer

8. KWH pulse

9. Voltage

10. Frequency

11. 24 Volt DC Supply.

(Remote Control)

A terminal box containing a terminal strip is also provided to facilitate the remote control of the following:

1. Voltage

2. Frequency

3. Normal stop

4. Emergency stop.

V

Inlet Piping

The System includes adequate means for support and flexible coupling of the upstream piping so as to minimize any mechanical loading of the prime mover. The inlet piping is capable of safe handling of geothermal fluids at pressures up to 625 psig and temperatures up to 500°F. All inlet piping is hydrostatically tested to the ASME Boiler and Pressure Vessel Code to meet or exceed a 300 lb. ANSI rating. The inlet piping of the System includes the following components:

1. 8-inch, 300 lb. ASA gate start and stop valve
2. 8-inch, 300 lb. ASA automtic gate stop valve, pneumatically-hydraulically actuated
3. Flex-coupling at prime mover inlet, 8-inch, 300 lb. ASA rating
4. Burst-type bypass plus relief valve.

VI

Drawings

The Geothermal Power Conversion System is furnished in conformity with the following drawings as prepared by the Hydrothermal Power Co., Ltd.

Drawing Number	Issue Date
1. B-13	As revised 1-18-78
2. B-14	As revised 5-9-80
3. B-20	As revised 5-11-80

APPENDIX 1

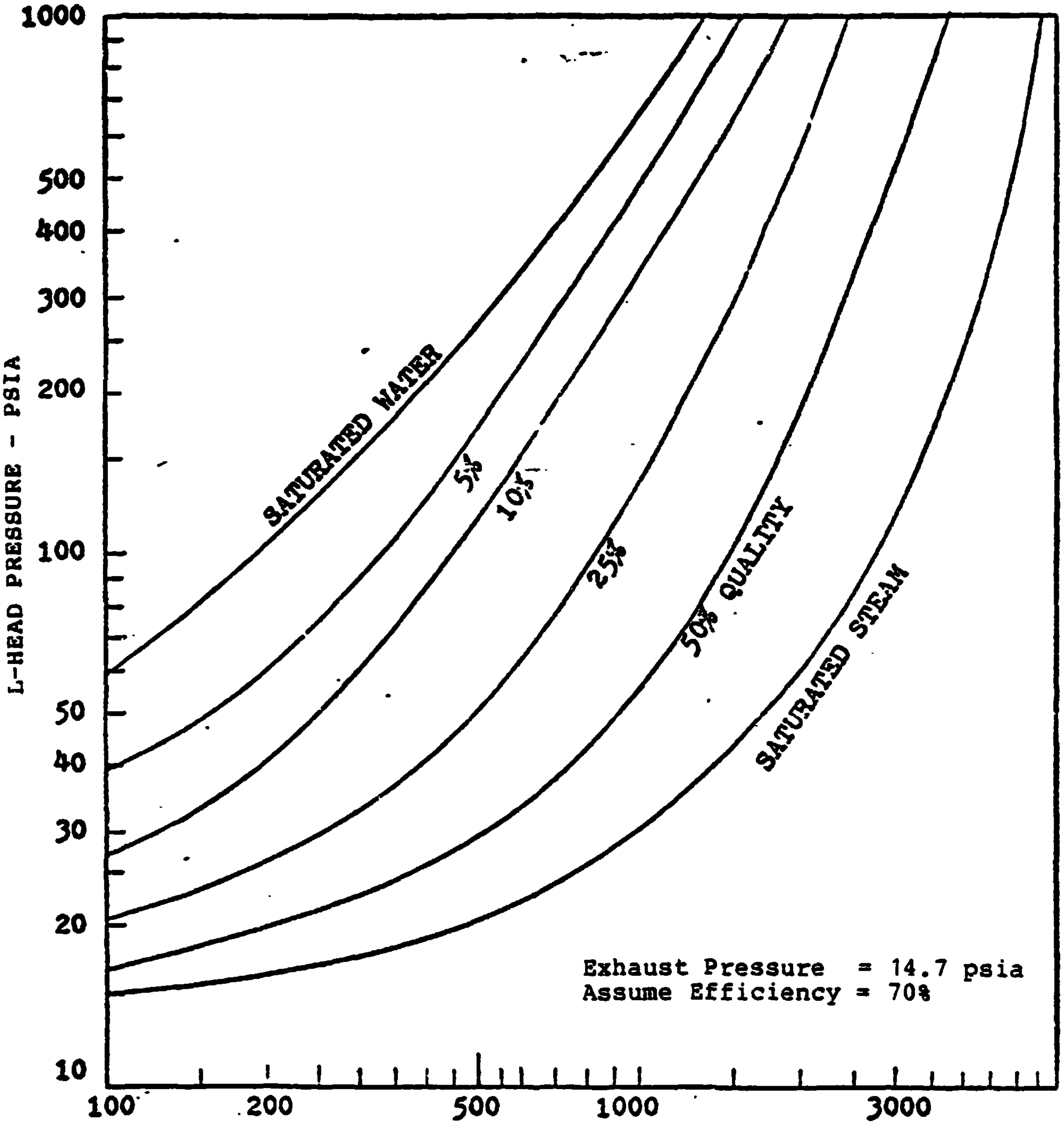
HYDROTHERMAL POWER SYSTEM PERFORMANCE

1250 KVA PLANT

	CASE I	CASE II
SIZE	16.5" Rotor diameter 25" Rotor length	same
POWER	1000 KW Prime Mover Shaft Output	same
RPM	4000; = 288 ft/sec tip velocity	same
FLOW RATE	135,000 lb/hr.	85,000 lb/hr.
ENTHALPY	424 Btu/lb. inlet	same
TEMPERATURE	444°F	same
PRESSURE	400 PSIA inlet 14.7 PSIA exhaust	400 PSIA Inlet 3 PSIA exhaust
QUALITY	0 at inlet	same
EXPANSION RATIO	347/1	1500/1
PRIME MOVER EFF.	70% of isentropic	65% of isentropic
SPECIFIC CONS.	135 lb/KWhr.	85 lb/KWhr.

NOTE: Assume Keenan and Keys Thermodynamic Properties of Water, 1969 edition.

A 9



SPECIFIC POWER OUTPUT $\frac{KW}{10^5 \text{ lb/hr}}$

HYDROTHERMAL POWER SYSTEM
PRIME MOVER PERFORMANCE

''YDROTHERMAL POWER CO., LTD.

2051 Woodlyn Road • Pasadena, California 91104 (213) 798-1005

27032 Via Callado • Mission Viejo, California 92675 • (714) 837-3081

REQUEST FOR QUOTATION

RFQ NO. 76-F-2 DATE April 21, 19

PRIORITY RATING DO-A2

CERTIFIED UNDER DMS REG. 1

TAXABLE NO [X] YES [ ]

CALIF.RESALE NO. SR AP 17-668216

TO BE CONSIDERED YOUR QUOTATION MUST BE RECEIVED BY HPC NO LATER THAN May . 17, 1976 DATE MATERIAL REQUIRED Sept. 15, 1976

DESCRIPTION OF ITEM(S)

AUTOMATIC GATE VALVE

(1) One 8" 300# ASA flanged, hydraulically actuated, Gate Valve. Body, bonnet, and yoke of ASTM A216 grade WCB; seats and wedges of ASTM 182-F6 and with Stellite No. 6 coating; and the stem of ASTM 182-F9. The valve shall be controlled by two input signals either one of which will automatically close the gate valve upon signal loss. Both signals shall be 12 VDC with 2 amp. maximum current. Signal loss from one of the inputs shall close the gate valve within one second, and a signal loss from the other input shall close the gate valve in approximately 15 seconds.

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O.B.	Estimated Shipping Weight	Terms	Date Material Will Be Shipped

Hereby Submit the Above Quotation	Phone No.	By (Typed Name)	Signature	Date
(The Contractor)				

GOVERNMENT SUBCONTRACT

Any Purchase Order issued by HPC as a result of your quotation will constitute a subcontract under Contract NAS7-100 between the United States of America and the (over)

McInnes STEEL COMPANY
— Corry, Pennsylvania —

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ULTRASONIC INSPECTION REPORT

MARY EGGEN
OCT 18 1976
DEPT. 827

P.O. A-11304

DATE	PRO NUMBER	
OCT 15 1976	69818	

TYPE OF EQUIPMENT: Branson Sonoray 600

FREQUENCY: 0.4 [ ] 1.0 [ ] 2.25 [X] 5.0 [ ] 10 [ ] 15 [ ] 25 [ ]

METHOD: CONTACT [X] WATER IMMERSION [ ]

TECHNIQUE: LONGITUDINAL WAVE [X] SHEAR WAVE [ ]

LINE VOLTAGE CONTROL: YES [X] NO [ ]

TRANSDUCER SIZE & SHAPE: 1" Dia.

REFERENCE STANDARD: 8/64" F.B.H.

PROCEDURE: ASTM- Block- 4340 80300

REMARKS & SKETCHES

This report is in addition to Ultrasonic Report dated Sept. 17, 1976.
Using the 80300 test block there is continuous clusters up to 85% (Ave - 25%) from ℄ to 1" off ℄, continuous for 15⅝" from the end in the 7.62" arm. Indications from #1 thru #5 are as follows, using the 80300 test block as 100%.

#1 - 70% Indication
#2 - 50% Indication
#3 - 85% Indication
#4 - 50% Indication
#5 - 20% Indication

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For locations of indication's see attached sketch.

Test By: G McCray S — C-1A Level II

PART DESCRIPTION OR DRAWING NO.: Ref Dwg # 12073524

C1

QUANTITY: 1

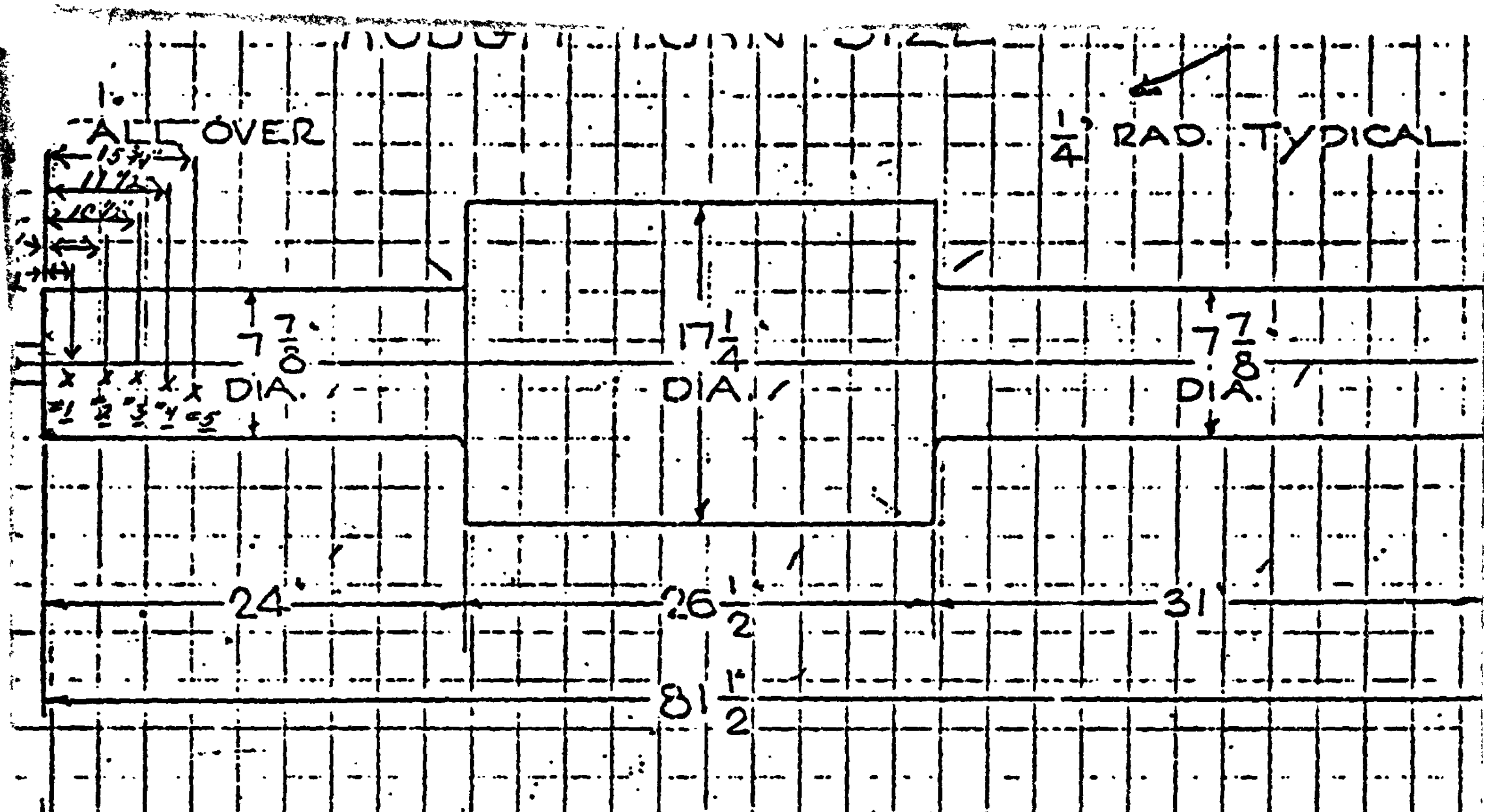
ITEM NO.:

TEST RESULTS:
ACCEPT [✓]
HOLD [ ]
QUESTIONABLE [ ]

DISPOSITION:
~~SHIP~~ [ ]
REWORK [ ]
RETURN MATERIAL [ ]

INSPECTION ENGINEER: David L. Gurner

CUSTOMER



1 - 2.25 MHZ 1" dia. - Indication 100% - 5% loss of B.R.
" " " " 1/2 dia. " 100% - 60% " " " "

2 - 2.25 MHZ 1" dia. - Indication 30% - No loss of B.R.
" " " " 1/2 dia. " 40% " " " "

3 - 2.25 MHZ 1" dia. Indication 20% - no loss of B.R.
" " " " 1/2" dia. " 30% " " " "

4 - 2.25 MHZ 1" dia. Indication 15% - no loss of B.R.
" " " " 1/2" dia. " 20% " " " "

5 - 2.25 M.H.Z. 1" dia. Indications 10% - No loss of B.R.
" " " " 1/2" dia. " 15% - " " " "

Calibration - 100% screen height back reflection.

C2

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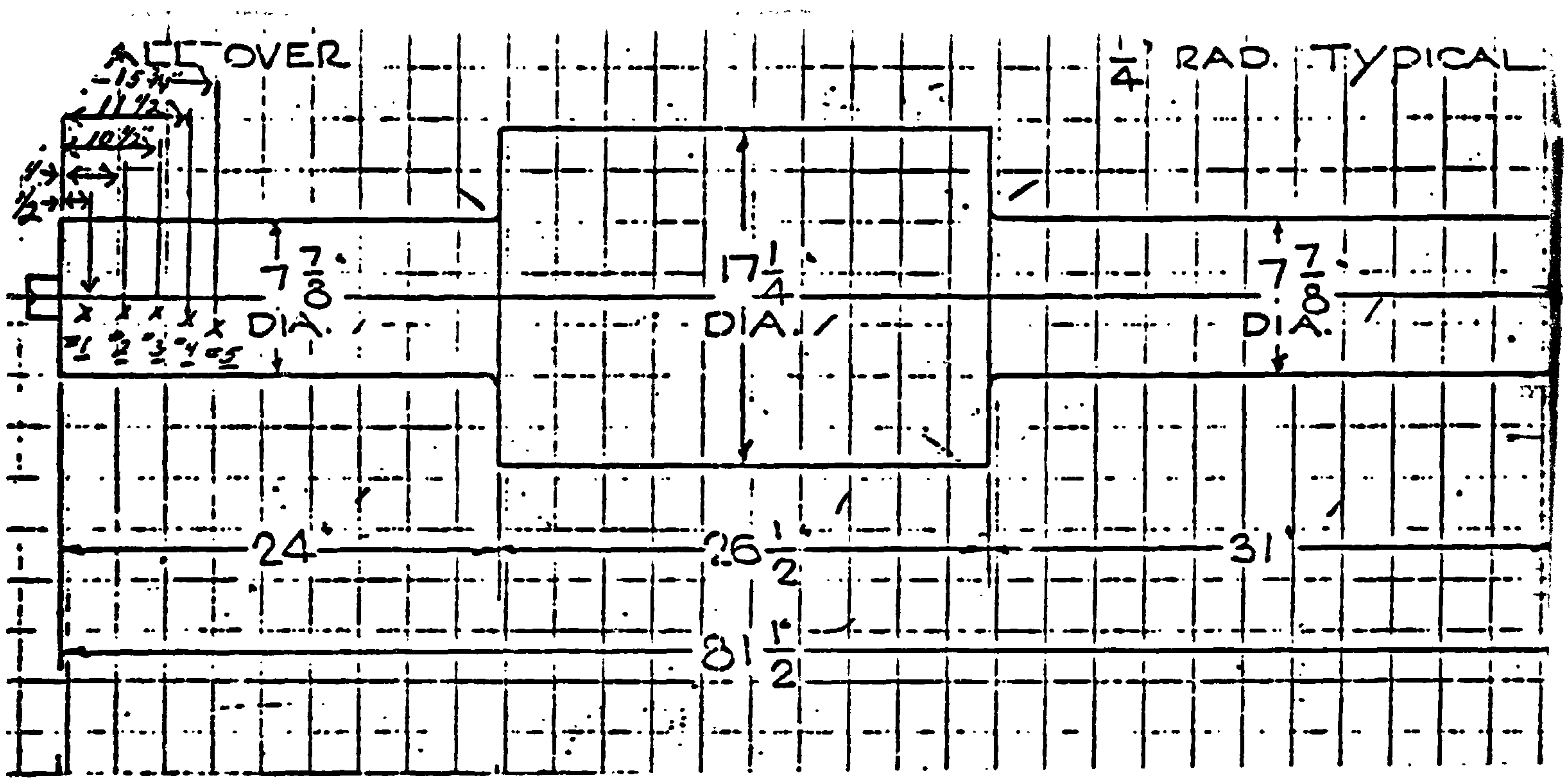
O.J.



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— Corry, Pennsylvania —

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ULTRA
INSPEC
REPO

P.O. A-11304

DATE	PRO NUMBER	
SEP 09 1976	69819	

TYPE OF EQUIPMENT: Branson Sonoray 600

FREQUENCY: 0.4 ☐ 1.0 ☐ 2.25 ☒ 5.0 ☐ 10 ☐ 15 ☐ 25 ☐

METHOD: CONTACT ☒ WATER IMMER...

TECHNIQUE: LONGITUDINAL WAVE ☒ SHEAR WAVE ☐

LINE VOLTAGE CONTROL: YES ☐ NO ☐

TRANSDUCER SIZE & SHAPE: 1" Dia.

REFERENCE STANDARD: 75% of full screen height B/R.

PROCEDURE: ASTM-A-418

REMARKS & SKETCHES

TYPE: 410 HEAT: 556027

Couplant #30 oil S/N - #1

RESULTS:

When tested in accordance with the above Procedure, these parts were found to be acceptable. (No reportable or unacceptable indications found.)

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INSPECTED BY: R. Butcher SNT-TC-1A Level II

PART DESCRIPTION OR DRAWING NO.	QUANTITY	ITEM NO.
Dwg # 12073-525	1	

C4

TEST RESULTS:
ACCEPT ☑
HOLD ☐
QUESTIONABLE ☐
REJECT ☐

DISPOSITION:
SHIP
REWORK ☐
RETURN MATERIAL TO SUPPLIER ☐
SCRAP ☐

INSPECTION NUMBER: David L. Turner

CUSTOMER

McInnes STEEL COMPANY
— Corry, Pennsylvania —

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ULTRASONIC INSPECTION REPORT

P.O. A-11304

DATE	PRO NUMBER
Sept. 17, 1976	69818

TYPE OF EQUIPMENT: Branson Sonoray 600

FREQUENCY: 0.4 ☐ 1.0 ☐ 2.25 ☒ 5.0 ☐ 10 ☐ 15 ☐ 25 ☐

METHOD: CONTACT ☒ WATER IMMERSION ☐

TECHNIQUE: LONGITUDINAL WAVE ☒ SHEAR WAVE ☐

LINE VOLTAGE CONTROL: YES ☐ NO ☐

TRANSDUCER SIZE & SHAPE: 1" Dia

REFERENCE STANDARD: 100% Calibrated B/12

PROCEDURE: ASTM-A-418

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Tested by: G. McCray S.N.T.-TC-1A Level II

PART DESCRIPTION OR DRAWING NO.	QUANTITY	ITEM NO.
Ref. Fin. Dwg. # 1207352	1	

C5

TEST RESULTS:
- ACCEPT ☒
- HOLD ☐
- QUESTIONABLE ☐
- REJECT ☐

DISPOSITION:
- SHIP
- REWORK ☐
- RETURN MATERIAL TO SUPPLIER ☐
- SCRAP ☐

INSPECTION ~~ENGINEER~~ David L. Yarmer

CUSTOMER REPRESENT. ....

MCINNES STEEL COMPANY
Corry, Pennsylvania 16407

SPECIALIZING IN STAINLESS & HIGH TEMPERATURE ALLOY
NUCLEAR - AIRCRAFT - ALLOY - CARBON - FORGINGS

COMPLETE HEAT TREATING, LABORATORY & TESTING FACILITIES
ULTRA SONIC INSPECTION

	CUSTOMER'S ORDER NO.	DATE	PRO NO.
	A11304	9-14-76	69819-00 F

SOLD TO

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SHIP TO

SAME
RECEIVING DOCK

SHIP VIA CONSOLIDATED - COLLECT - PARTIAL

CUSTOMER SPECIFICATION	TYPE	NUMBER OF PIECES	WEIGHT
A-473 & DWG.	410	1 PC.	2278#

B/P	SIZE	SERIAL NO.
12073-525	PER DWG.	#1

CONDITION: NORMALIZED & TEMPERED & STRESS RELIEVED

CHEMICAL ANALYSIS

ITEM NO.	HEAT NO.	C.	MN.	P.	S.	SI.	CR.	NI.	MO.	V.	AL.
1	556027	.12	.50	.017	.011	.39	12.37	.39			

TI.	CB.	CO.	PB.	CU.	SN.	FE.	TA.	B.

MECHANICAL PROPERTIES

ITEM NO.	SERIAL NO.	DIA.	YIELD P.S.I. .2 % OFF SET	ULTIMATE TENSILE P.S.I.	ELONG. %	RED. AREA %	HARDNESS BHN	HARDNESS ROCK-C	JOMINY HARDEN-ABILITY	GRAIN SIZE	IMPACT FT. LBS
1			76,500	100,000	23.0	73.9	229/229/229/248				

MELT SOURCE ARMCO

ULTRA-SONIC INSPECTION: PER A-418, REPORT ATTACHED	MAGNETIC PARTICLE INSPECTION:
MACROETCH CLASSIFICATION:	BEND TEST RESULT:
INTERGRANULAR CORROSION RESULT:	LIQUID PENETRANT INSPECTION RESULT:

THIS IS TO CERTIFY THAT, TO THE BEST OF OUR KNOWLEDGE AND ... ABOVE MATERIAL HAS BEEN MANUFACTURED IN ACCORDANCE WITH THE DRAWINGS, PURCHASE ORDERS AND SPECIFICATIONS, AND COMP... ...NSIONAL REQUIREMENTS AND WORKMANSHIP.

C 6

McINNES STEEL COMPANY

(CHIEF METALLURGIST)

STEEL COMPANY
Corry, Pennsylvania 16407

NUCLEAR - AIRCRAFT - ALLOY - CARBON - FORGINGS

COMPLETE HEAT TREATING, LABORATORY & TESTING FACILITIES
ULTRA SONIC INSPECTION

	CUSTOMER'S ORDER NO	DATE	PRO NO.
	A11304	10-1-76	69818-00 M

SOLD TO

SHIP TO SAME

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OF POOR QUALITY

SHIP VIA CONSOLIDATED - COLLECT - COMPLETE

CUSTOMER SPECIFICATION	TYPE	NUMBER OF PIECES	WEIGHT
A-473 & DWG.	410	1 PC.	2482#

S/P	SIZE	SERIAL NO.
12073-524	PER DWG.	

CONDITION: NORMALIZED & TEMPERED

CHEMICAL ANALYSIS

ITEM NO.	HEAT NO.	C.	MN.	P.	S.	SI.	CR.	NI.	MO.	V.	AL.
1	656451	.11	.44	.014	.021	.41	12.79	.21			

TI.	CB.	CO.	PB.	CU.	SN	FE.	TA.	B.

MECHANICAL PROPERTIES

ITEM NO.	SERIAL NO.	DIA.	YIELD P.S.I. .2 % OFFSET	ULTIMATE TENSILE P.S.I.	ELONG. %	RED. AREA %	HARDNESS BHN	HARDNESS ROCK-C	JOMINY HARDEN-ABILITY	GRAIN SIZE	IMPACT FT. LBS.
1			76,000	100,000	20.0	68.8	201/207/207/207				

MELT SOURCE ARMCO

ULTRA-SONIC INSPECTION: PER A-418, REPORT ATTACHED	MAGNETIC PARTICLE INSPECTION:
MACROETCH CLASSIFICATION:	BEND TEST RESULT:
INTERGRANULAR CORROSION RESULT:	LIQUID PENETRANT INSPECTION RESULT:

THIS IS TO CERTIFY THAT, TO THE BEST OF OUR KNOWLEDGE AND BELIEF THE ABOVE MATERIAL HAS BEEN MANUFACTURED IN ACCORDANCE WITH THE DRAWINGS, PURCHASE ORDERS AND SPECIFICATIONS, AND COMPLIES WITH DIMENSIONAL REQUIREMENTS AND WORKMANSHIP.

McINNES STEEL COMPANY

C 7

(CHIEF METALLURGIST)

SHIPPING ORDER

A. FINKL & SONS CO.

10735 Sessler Street
South Gate, California 90280
Phone: 773-4040

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No. 4657

SHIP TO: ~~SXAMEX~~ FORGE DIE CO
MONTERY PARK CALIF

CHARGE TO: HYDROTHERMAL POWER CO LTD
27032 VIA CALLADO
MISSION VIEJO CALIF 92675 35

Date 11/5/76
Order No. 76-M-1C-1A
F.O.B.
Via:

✓	QUANTITY	MATERIAL	WEIGHT	PRICE	EXTENSION
		EF-4142 VAC. DEGASSED, QUENCHED			
		AND DOUBLE TEMPERED TO			
		269/302 BHN, 28/32 RC			
		FINISHED SIZES			
	1	10 X 32.5 X 38			

D1

SAW PER YOUR PRINT
GRIND TOP & BOTTOM CLEAN UP
(3-P-S)

Delivered By: [illegible]
Date Delivered: 11/11/76
Received By: [illegible]

CUSTOMER COPY

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A Finkl & Sons Co.

METALLURGICAL REPORT

USTOMER A. Finkl & Sons Co. (CA.)   DATE November 2, 1976

O. 9/28/76/01   QUANTITY 1 Pc.   S. O. 15645

EM 10" X 32.5" X 38", Finish Sizes

RADE EF-4142 Vac. Degassed, Quen. & Dbl. Temp.

FORGED SURFACE

ECIFICATION

RECEI...
NOV 1976
A. FINKL & SONS CO.

Heat No.	Mill	Class	C	Mn	P	S	Si	Ni	Cr	Mo	V	Cu			Grain Size
.60576	X	BE	.42	.88	.015	.021	.30	-	.83	.19					

Jominy	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	18	20	22	24	26	28	30	32

Test No.	Test Dia.	Test Direction or Location	Yield Strength PSI	Tensile Strength PSI	Elongation % in 2"	Reduction of Area %	Fracture Rating	Brinell Hardness (HB)	Impact Ft. - Lbs.	Serial No.
equired:								269/302		
								293/293		

eat Treatment

Remarks

Subscribed and sworn to before me this
day of November 3, 1976
Notary Public Martha Vertentes

D2

WITNESSED

above agrees with the official company records.

I. Valentine

PHYSICAL ______ FOR ______ DATE ______

SURFACE ______ FOR ______ DATE ______

F-57—Rev. 8-75

A. FINKL & SONS CO.

ULTRASONIC REPORT

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2 cop./C.A.R.

DATE 11-2-76

CUSTOMER Finkl (Cal.)

CUSTOMER ORDER NO. 9/28/76/01

DESCRIPTION 10 x 32.5 x 38"

SHOP ORDER NO. 15645

HEAT NO. 160576

QUANTITY TESTED 1pc

SONIC UNIT SPERRY UM 715

SEARCH UNIT SPERRY
2.25 MHz - 1.125 Dia. Qtz

COUPLANT 30 OIL

TEST BAR 4/64" F.B. HOLE

TEST BAR.

SENSITIVITY ADJUSTMENT:

SCAN FACE - 4/64" F.B. HOLE = 2" pip (Swp/pk) on SCOPE

RESULTS:

No indications found & loss in a full screen back reflection did not exceed 10%

J. P. Wuk

Q. C. Manager

Esco's P/O No. 5894338

NIPPON STEEL CORPORATION

MILL SHEET

Head Office: ...3, Otemachi, Chiyoda-Ku,
Yawata Works: 1-1 Edam... Yawata Hig...

CONTRACT NO. : 5-868-H1-5-0-7006 *

COMMODITY : HOT ROLLED STAINLESS STEEL PLATES

SPECIFICATION : ASME SA-240 TYPE304 AS BELOW**

CUSTOMER : MITSUBISHI INTERNATIONAL CO., PORTLAND

SHIPPER : MITSUBISHI CORPORATION

MILL SHEET NO. : 1281

DATE OF ISSUE : Nov., 14, 1976

DATE OF INSPECTION: Nov., 12, 1

Size	No. of Product	Weight LB / KG	Heat No.	Test Piece No.	Inspection No. Head No. / Running No.	Tensile Test Yield point LB/IN2	Tensile St.	El. %	Impact Value		HB	C	Si	Mn	P	S	Cu	Ni	Cr	Mo	V	Ti
1-3/4"X96"X240"	1	11902 / 5435	03163	7536	34257501	32300	87300	640			125	070		103	31	9		915	1835			
2-1/2"X96"X120"	1	8464 / 3840	03079	7534	33304101	32700	85600	620			138	064		102	30	4		920	1865			
2-1/4"X96"X120"	1	7562 / 3430	03122	7538	33304501	32900	85500	650			129	067		90	30	0		910	1020			
2"X96"X240"	1	13823 / 6270	03182	7537	34257601	33100	87500	640			136	065		100	30	4		920	1845			
3-1/2"X60"X144"	1	8995 / 4080	03079	7535	33071801	32700	85500	630			129	064		102	30	4		920	1865			
TOTAL	5	23055 LB		50028																		

HYDRO THERMAL POWER CO.
25721 OBRERO UNIT B
MISSION VIEJO, CA. 92675

PO#K76-M-1-C-5-A
ESCO SO#5829592 W10-4-76

Mill Sheet Control Code: 304 092

Remarks: HEAT TREATED

*ASTM-A240/A167 ASME SA-240 WITH
SUMMER '74 ADDENDUM
QQ-S-766C AND MIL-S-5059C
EXCEPT CLAUSES:-
(A) MAGNETIC PERMEABILITY, PACKING AND MARKING WHICH TO BE DELETED
(B) PRODUCTION PROCESS, TEST ITEM AND TEST METHOD

WE HEREBY CERTIFY THAT THE MATERIAL DESCRIBED HEREIN HAS BEEN MADE IN ACCORDANCE WITH THE RULES OF THE CONTRACT

10-14-76

Manager of Yawat

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D4

G.O. CARLSON *Inc.*
Producers of Stainless Steel, Nickel Alloys and Titanium
THORNDALE, PA 19372

TEST REPORT

GOC # 66020

DATE 10/21/76

CUSTOMER ORDER NUMBER: 76-M-1-C-2A

T. CODE: S

CUSTOMER MARK: 76-M-1-C-2A

SOLD TO:

HYDROTHERMAL POWER CO LTD
25721 OBRERO UNIT B
MISSION VIEJO, CA 92675

TYPE AND SPECIFICATIONS:

304 ASME SA-240, WINTER 1975
HRAP

DESCRIPTION	HEAT								COND
5.2500 GA. SKETCH A-7	656673-1	TT	38000	83500	58	71	157		

Ultrasonic Report Attached.

D5

QTY	HEAT	C	MN	P	S	SI	CR	NI
1	656673-1	.050	1.44	.019	.012	.49	18.50	8.83

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Sworn to and subscribed before me this ______ day of ______

I hereby certify the above figures are correct as contained in the records of the corporation

Mildred M Atkinson

10/21/76

Producers of Stainless Steel, Nickel Alloys and Titanium

THORNDALE PA 19372

REFER TO THIS NUMBER IN CORRESPONDENCE 66020

CODE	UNIT		CUSTOMER ORDER	CUSTOMER MARK
569 LA	2	S	76-M-1-C-2A	76-M-1-C-2A

ACTUAL ROUTING K&G/WEST CARLOADING PREPAID

SOLD TO

HYDROTHERMAL POWER CO LTD
25721 OBRERO UNIT B
MISSION VIEJO, CA 92675

SHIP TO

A. Finkl and Son
C/O Bud Finkl
10735 Sessler Street
Southgate, CA.

TYPE AND SPECIFICATION

304 ASME SA-240, WINTER 1975
HRAP

ITEM	DESCRIPTION					WEIGHT
1	5.2500 GA. SKETCH A-7 F/C PERIPHERY & HOLES TOL. PERIPHERY + 1/4 - .000 HOLES + .000 - 1/4	'S'	1	1	C	1990

**** CHEMICAL ANALYSIS ****

ITEM- 1 QTY- 1 HEAT- 656673-1

C	MN	P	S	SI	CR	NI
.060	1.44	.019	.012	.49	18.50	8.83

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D6

GUC 66020 CUSTOMER HYDROTHERMAL POWER COMPANY P.O.# 76-M-1-C-ZA

DATE 10/15/76 TYPE 304 COND. HRAP FORM PATTERN (SKETCH)

U.T. PROCEDURE (X) LONGITUDINAL: PER ASTM - A435

( ) SHEAR :

SCAN SPEED: 6"/Sec. Max OVERLAP: 10%Min. METHOD CONTACT COUPLANT WATER & DETERGENT

EQUIPMENT SPERRY UM 775 PULSER 10-S #2 SCANNING 100% ONE MAJOR SURFACE

PART IDENTIFICATION			DESCRIPTION	TRANSDUCER			SETTINGS				CALIBRATION	
ITEM	QUAN	HEAT	SIZE	MAKE	BEAM	SIZE	FREQ.	SENS.	SWEEP	BR	NOTCH DEPTH	HOLE DIA.
1	1	656673-1	5.250 Ga. SKETCH	AERO	STR	1"Ø	MHZ 2.25	X1-4	.5	2	N/A	N/A

D7

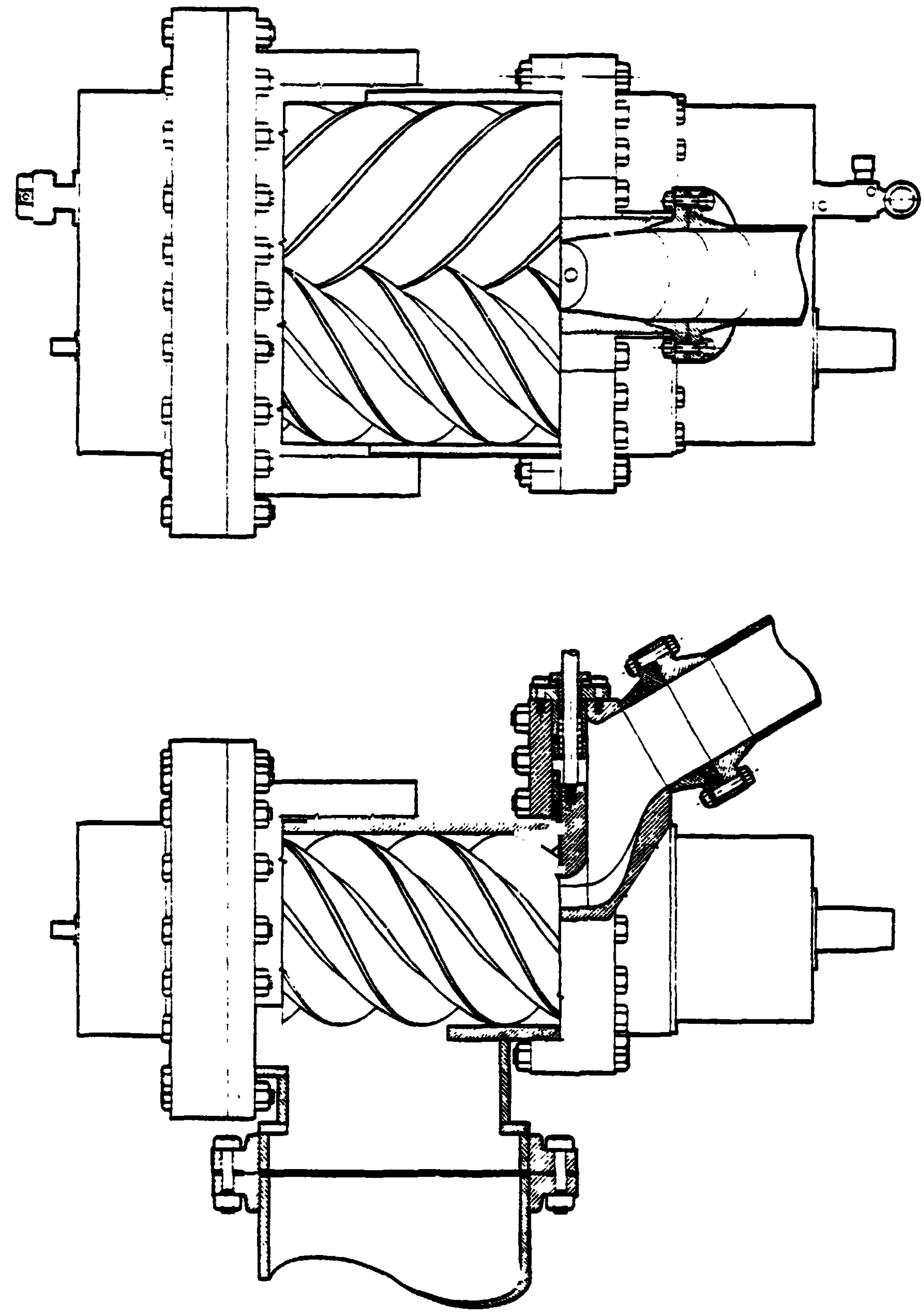
RESULTS: THE ABOVE MATERIAL WAS TESTED BY THE LONGITUDINAL WAVE METHOD AND FOUND TO BE ACCEPTABLE TO THE ABOVE PROCEDURE.

INSPECTOR(S) Jay A. Zappacosta

QUALIFIED: SNT-TC-1A (X) LEVEL II (X) MIL-STD-271E

CUSTOMER REP. —

FORM ULT Rev. 2



E

HYDROTHERMAL POWER CO., LTD.

QUALITY CONTROL PROCEDURE

In order to assure the absolute conformance of incoming materials, purchased parts, machining or processing of materials and purchased parts, each such incoming item received by HPC secured for integration into the HPC Power Conversion System, is to be checked against the purchase order and purchase order drawing as to both quantity and quality.

A record will be maintained by HPC showing the results of checking, inspection, and measurement upon receipt of incoming materials, purchased parts, machining or processing of materials and purchased parts.

Such record shall be in the following form:

A.	PART NO. or PURCHASE ORDER NO.	
B.	DESCRIPTION of PART or TASK	
C.	DRAWING NO.	
D.	(1) DATE of PURCHASE ORDER	
	(2) DATE of RECEIPT BY HPC	
	(3) DATE of INSPECTION	
E.	MANUFACTURER, VENDOR or SUPPLIER	
F.	CRITICAL MEASUREMENTS TAKEN BY:	
G.	CRITICAL MEASUREMENTS TAKEN DATE:	
H.	CRITICAL MEASUREMENTS RECORDED ON SHOP DRAWING or COPY of PURCHASE ORDER (1)BY:	
	(2)DATE:	
I.	ACCEPTANCE DATE	
J.	COMMENTS	

F

PART NO. or P. O. NO. ____________

Brief Summary of Torsional Frequency Analysis

A lumped-mass mass model was constructed for the entire system. This model consists of five "inertias" (actually moments of inertia) which represent respectively:

Female & Male Rotors & Shafting of the Compressor

The First Coupling

The Speed Reducer

The Second Coupling

The Alternator (Fan, Rotor & Exciter)

These five inertias are coupled by four uniform shafts. The numerical values of the inertias and of the torsional rigidities of the shafts were determined from values on the blueprints or were calculated from the physical dimensions provided. All calculations were made with reference to the Male Rotor Axis.

The analysis of the Free-free torsional vibrations of the system is accordingly reduced to an eigenvalue problem. The eigenvalues are found to be the roots of a tenth-order algebraic equation in the circular frequency w*. One root, as expected, is W-0, which corresponds to a rigid body rotation of the entire system. Thus the determination of the eigenvalues amounts to the determination of the roots of a fourth order equation in W^n. The four roots correspond to the frequencies n (hz) of the four principal modes of torsional vibration of the system which have one, two, three or four nodes corresponding to the increasing numerical value of the frequency. Usually the lower frequencies are those of particular interest in practice. The natural frequencies of the higher order modes are generally beyond the operating frequencies of a system.

*The tenth order equation can be treated as a fith order equation because only even powers of W occur in it.

The four frequencies n_i ($i = 1,..4$) were determined for three different speed ratios for the five mass system. The results are as follows:

Case I; Speed Ratio 1800/3000

$n_1 = 64$ hz

$n_2 = 189$ hz

$n_3 = 315$ hz

$n_4 = 609$ hz

Case II; Speed Ratio 1800/4000

$n_1 = 52$ hz

$n_2 = 191$ hz

$n_3 = 294$ hz

$n_4 = 574$ hz

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Case III; Speed Ratio 1800/5000

$n_1 = 47$ hz

$n_2 = 209$ hz

$n_3 = 308$ hz

$n_4 = 629$ hz

These values have been determined subject to certain approximations which should be noted:

i) Continuous mass distributions have been lumped

ii) Continuous parameter distributions e.g. torsional rigidities have been lumped

iii) Gear assembly is assumed to be rigid. Gear & tooth flexibility is neglected and gear backlash is ignored

iv) Frictional energy dissapation e.g. in flexible couplings is considered to be neglegible throughout the system

v) Flexural vibrations have not been considered

A lengthier and more detailed analysis would be needed to include the effects of these approximations.

References:

Two basic works of reference are "Practical Solution of Torsional Vibration Problems" by W. K. Wilson, Wiley, New York, 1956 (Two volumes) and "Handbook on Torsional Vibrations" by E. J. Nestorides, Cambridge University Press, 1958.

G3

philadelphia gear corporation

November 15, 1977

Hydrothermal Power Company, Ltd.
25721 Obrero, Unit B
Mission Viejo, California 92675

Attention: Mr. J.A. Sprankle

Subject: Your P.O. #76-M-4
Our Order #489254
Efficiency curves

Gentlemen:

To confirm our meeting of 11-9-77, the efficiency curves that were delivered to you on 10-25-77 were derived in a similar fashion as outlined to you in a July 21, 1977 letter from our Michael Hardiman. The empirical data on the above order has indicated about an 8% error in the calculated constant that we used in our heat-balanced equation. This error, in all probability, is caused by aeration of the oil. The empirical formula accounts for this and includes radiant heat losses as well.

Hopefully, this is the information that Dr. McKay is looking for. Please advise us if there is anything else we can do to bring this matter quickly to a close.

Very truly yours,

PHILADELPHIA GEAR CORPORATION

Mark Alter

Mark M. Alter
Sales Representative

MMA/fj

cc: Dr. R.A. McKay - Jet Propulsion
cc: John L. Gillaspy - Anaheim

Earl Gesenheim 1-213-577 0500

MARK M. ALTER
Sales Representative
philadelphia gear corporation
2600 EAST MIRALOMA WAY
ANAHEIM, CALIFORNIA 92806 (714) 630-7800

H1

July 21, 1977

Hydrothermal Power Co., Ltd.
2051 Woodlyn Road
Pasadena, California 91104

Attention: Mr. J. A. Sprankle,
Business Manager

Reference: Your P.O. #76-M-4
Our Order #489254
Your Letters of '/12/77 and 6/14/77

Gentlemen:

I appreciate your concern in receiving the required efficiency data as well as your demonstration of good faith with the trustee account. As you know, we have submitted one set of efficiency data but unfortunately, the inlet oil temperature has been changed rendering this data unusable for your purposes. Also, you must realize that the calculation tools available today are not sophisticated enough to guarantee the 1/2 of 1% maximum error you have requested.

A telephone conversation between Dr. McKay and myself indicated that an explanation of our testing/calculating heat loss method may suffice in satisfying this requirement.

I have attached three sheets covering the derivation of our heat balance equation and the particular lubricant used at our test stands. As you will note, empirical data has indicated about an 8% error in the calculated constant. This error, in all probability, is caused by aeration of the oil. The emperical formula accounts for this and includes radiant heat losses as well.

Hydrothermal Power Co., Ltd.
Mr. J. A. Sprankle
July 21, 1977

If possible, Dr. McKay should run both loaded and unloaded tests using a torque cell and tachometer to verify the accuracy of our constant under his test stand conditions. Once this is established, the accuracy he requires for his testing should be attainable.

I hope this data will suit your requirements. If there are any questions, please contact me.

Very truly yours,

PHILADELPHIA GEAR CORPORATION

Michael J. Hardiman

Michael J. Hardiman, Manager
Special Products Division

enc.
rc
cc: Dr. R. A. McKay/Calif. Institute Tech.
J. Gillaspy/P.G.C., Anaheim, Calif
J. Pooler/P.G.C., King of Prussia, Pa.
R. Meyers/P.G.C., King of Prussia, Pa.

DERIVATION OF HEAT BALANCE EQUATION

REF: 462140

TYPE OF LUBRICANT: MOBIL DTE LIGHT (SPEC. SHEET ATTACHED)

DIMENSIONALLY

$$HP = \frac{\frac{GAL}{MIN} \times \frac{\#}{GAL} \times \frac{BTU}{\# - {}^\circ F} \times F^\circ}{\frac{BTU}{HP - MIN}}$$

MOBIL REPORTS THE FOLLOWING WITH REFERENCE TO DTE LIGHT

WEIGHT PER GALLON = 7.251 LB

SPECIFIC HEAT = $.481 \frac{BTU}{\# - {}^\circ F}$

INSERTION INTO THE DIMENSIONAL EQUATION YIELDS

$$HP = \frac{(GPM)(7.251)(.481)(\Delta T)}{42.45}$$

COLLECTING ALL CONSTANTS

$$HP = .0822\,(GPM)(\Delta T)$$

BY MONITORING SEVERAL UNITS ON TEST USING A TORQUE CELL TO MEASURE INPUT TORQUE AND AN ELECTRONIC TACHOMETER TO MONITOR SPEED THE CONSTANT .0822 WAS EMPIRICALLY FOUND TO BE EXCESSIVE. USING A BROAD RANGE OF SIZES AND/OR TYPE OF UNIT THE CONSTANT .0762 WAS FOUND TO YIELD MORE ACCURATE RESULTS. THIS ACCOUNTS FOR CHURNING, AERATION, ETC.

EMPIRICALLY

$$HP = .0762(GPM)(\Delta T)$$

OIL

Mobil D. T. E.® 20 Series

Hydraulic Oils

The Mobil D.T.E. 20 series of high quality oils has been developed specifically to satisfy the requirements of hydraulic systems using the newer, high-pressure, high-output pumps. The large growth in hydraulic operation of systems on mobile equipment has resulted in the development of pumps that are smaller, yet deliver greater volumes of fluid at higher pressures than were thought practicable a few years ago. Since response time is improved when a smaller volume of fluid at higher pressure is used, high pressure pumps are also being applied increasingly in hydraulic systems of machine tools and other industrial applications. Pump vanes or pistons, control valves, and linear and rotary actuators of hydraulic systems all operate with boundary or mixed film lubrication so that wear protection must be provided by thin oil films. As pressures and operating speeds are increased, the loading on these thin films is increased, and the fluid must provide greatly enhanced antiwear or film strength characteristics to protect against excessive wear. At the same time, oxidation and foaming resistance, demulsibility, and rust and corrosion protection must be maintained at high levels to avoid other operating problems.

PRODUCT DESCRIPTION

The Mobil D.T.E. 20 series was developed in cooperation with pump and hydraulic system component manufacturers to provide the superior antiwear and film strength characteristics necessary for the new high pressure hydraulic pumps that are coming into wide use. They are formulated from high quality, chemically stable, high VI base stocks combined with additives chosen to provide the specific properties required in hydraulic fluids. Compared to the best automotive oils, they provide superior performance characteristics including demulsibility, rust prevention, and resistance to deposit formation, and equal antiwear protection. In addition, the viscosities are chosen to accurately meet the requirements of hydraulic pump builders and coincide with the new ASTM viscosity grades. Furthermore, their functional characteristics permit a wide range of industrial applications other than in hydraulic systems.

In the development of the Mobil D.T.E. 20 series, extreme care was given to the selection of antiwear agents and rust inhibitors which will not interfere with water separating characteristics. The combination of additive components was carefully balanced with the base stocks to ensure that the final products provide the best obtainable combination of antiwear, demulsibility, oxidation resistance, rust protection and foam resistance properties. A protective barrier is provided by a thin film of oil which prevents the rusting of metal parts in the presence of small

Characteristic	Mobil D.T.E. 24	Mobil D.T.E. 25	Mobil D.T.E. 26
Gravity, API	31.7	30.6	29.9
Specific Gravity	0.867	0.873	0.877
Pour Point, max. F (C)	0 (—18)	0 (—18)	0 (—18)
Flash Point, min. F (C)	395 (202)	400 (204)	400 (204)
Viscosity			
SUS at 100 F	153	225	300
SUS at 210 F	43	49	53
cSt at 38 C	33	48.5	65
cSt at 99 C	5.1	7.0	8.2
Viscosity Index	95	95	95
Rust, ASTM D 665, A & B	Pass	Pass	Pass
Color, ASTM, Max.	2.0	2.5	3.5
Cincinnati Milacron, Inc. C M Co Heat Test 1 Week at 275 °F (135 °C)	Pass	Pass	Pass

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amounts of water or condensed moisture from the air. They have shown superior fluid durability (resistance to deposit formation) and exceptional service performance.

TYPICAL CHARACTERISTICS

Physical and chemical characteristics of the Mobil D.T.E. 20 oils are shown in the data sheet table. Those values which are not shown as maximums or minimums are typical characteristics which may vary slightly.

APPLICATION

Mobil D.T.E. series oils are recommended for hydraulic applications in industrial, marine and mobile service. These oils are Mobil's primary recommendation for all hydraulic applications including the newer, high-pressure systems in industrial service, especially when the equipment manufacturer specifies the use of antiwear type hydraulic fluids.

Since Mobil D.T.E. 20 series oils are the primary hydraulic recommendation at all times, application consists mainly of selecting the proper grade for the particular system. Selection of the correct viscosity is based on ambient and bulk fluid temperatures, as well as the operating pressure and design characteristics of the pump and system. Mobil D.T.E. 24 is recommended frequently for small gear pumps, vane pumps and both radial and axial piston pumps. Mobil D.T.E. 26 is recommended as the oil meeting the viscosity requirements of vane pumps and gear pumps operating at high pressures or temperatures. It is also recommended for radial and axial piston pumps. Mobil D.T.E. 25 meets the viscosity requirements for many vane pumps and is an excellent product to simplify plant inventory, when a single oil is desired to replace one of 150 SUS (32 cSt) at 100 F (38 C) and another oil of 300 SUS (65 cSt) at 100 F (38 C).

Some hydraulic equipment manufacturers specify a preferred viscosity (at 100 F) for vane and axial piston pumps. Mobil D.T.E. 24 is recommended where a 150 second oil is specified; Mobil D.T.E. 25 for a 250 second oil and Mobil D.T.E. 26 for a 300 second oil. Other manufacturers base their recommendations on pump pressures. When this pressure is below 1000 psi (70 kg/cm^2), Mobil D.T.E. 24 is recommended; below 1500 psi (105 kg/cm^2), Mobil D.T.E. 25; and over 1500 psi (105 kg/cm^2), Mobil D.T.E. 26.

Mobil D.T.E. 20 series oils are also recommended for many circulation, splash, bath and ring oiling systems supplying lubricant for the bearings and gears of industrial machinery. Their adaptability to these applications can greatly reduce inventory and lubrication costs where these oils are required for hydraulic use. They are not recommended for steam turbine nor ammonia refrigeration compressor service. Where no unusually high temperatures are involved, Mobil D.T.E. 26 may be used as the lubricant in single-stage reciprocating compressors up to 80 psig (5.6 kg/cm^2) or in two-stage reciprocating compressors up to 150 psig (10.5 kg/cm^2) of the type normally used for producing "plant" air.

ADVANTAGES

Mobil D.T.E. 20 series oils offer the following advantages and benefits:

- Outstanding antiwear performance
- High resistance to oxidation degradation
- Good protection against rust corrosion
- Good foam resistance
- Good water separation in hydraulic systems
- Correct grades for hydraulic service
- Worldwide availability

Mobil Oil Corporation PRODUCT PROMOTION DIVISION 150 EAST 42ND STREET, NEW YORK, NEW YORK 10017

5-85-008
7/18/75

PH ADELPHIA GEAR CORPORATION

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UNIT TEST REPORT

PERFORMED 5/4/77 thru	PARTIAL / FINAL UNIT	Major Corrections Necessary & Rerun [ ] / Accepted [X]	ORDER NUMBER 489254

DEPARTMENT	COPIES TO
ENGINEERING	
TEST LAB.	✓
QUALITY CONTROL	✓
FILE	
SALES	
CUSTOMER(S) INSPECTOR	✓
APPROVAL SIGNATURE	

Size & Type 8 HS Serial Number 121680

Rated Horsepower 1341 Input RPM Note 1

Service Factor 1.33 Output RPM 1800

Ratio Note 1 Reversable No Output Torque ---

TEST CONDITIONS

When load or extended test is run record data on P.G.C. Sheet No. EPL-2 until temperatures level off for the particular running conditions.

Total Running Time * H.S. Shaft Speed *

H.S. Shaft Rotation CW Shaft Which Was Driven HS

Amount of Load Applied None Method 50 HP Reeves

Type of Lubrication System External force feed

Location of Oil Level None maintained

Bearing(s) & Seal(s) Which Require Grease None

Type of Lubricant used on test Mobil Vaprotec Light

Oil Pressure Cold 25 PSI Oil Pressure Hot 25 PSI

Ambient Temperature 75 Oil Inlet Temp. *

Unit Sump Temp. °F. * Seal Temp. HSS -- LSS --

Bearing Temp's: HSS * LSS * INT. -- INT. --

" " " * * " -- --

Oil Leakage: Piping None Caps None Seals None

Splits None Housing None Note all leaks and Corrective Measures

VIBRATION (MILS)

HSS * LSS *

Housing Vertical NM

Horizontal NM Axial NM

SOUND LEVEL Ambient Sound NM Overall Sound NM High Octave NM Freq. NM

All accessories mounted & functioning - gages, etc. Yes

NOTES, REJECTIONS, CORRECTIONS, ETC. * See attached data sheets

Note 1	Group	Input Speed	Ratio
	1	3000 RPM	1.666:1
	2	4000 RPM	2.216:1
	3	5000 RPM	2.781:1

H7

TEST PERSONNEL	ASSEMBLER	APPROVAL
J.Gorden, B.Bailey, R.Scheler		W. Tarez

NO. OF ADDITIONAL DATA SHEETS ATTACHED 4

DATE 5-16-77

SIGNED J. Glendey

ORDER NO. 48-423-7-1

SERIAL NO. 121680

UNIT TEMPERATURE DATA

(Always accompany with P.G.C. Sheet No. ETL-1)

TIME	SPEED HSS	INPUT LOAD	OIL FLOW GPM	OIL PRES. PSI	COOLER WATER INLET	COOLER OIL INLET 6	COOLER OIL OUTLET 6	SUMP 6	HOUSING 7	BEARINGS (Label) LS INPUT 8	LS OUTPUT 2	HS INPUT 3	HS BLD 4	5	6	VIBRATIONS LSS 7	HSS 8	REMARKS
0930	1800	SPIN TEST	13	25	OFF	84	92	92	85	91	100	100	91			0.15	0.4	
0945	1800	"	13	25	OFF	93	97	97	92	99	106	107	100			0.15	0.4	
1000	1800	"	14	25	OFF	97	101	101	96	102	104	111	121			0.15	0.4	REPAIR WIRE NO 2,3
1015	1800	"	14	25	OFF	102	106	106	99	107	107	113	123			0.15	0.3	
1030	1800	"	14	25	OFF	108	111	111	103	111	112	117	126			0.15	0.35	
1045	1800	"	14	25	OFF	110	113	113	106	114	114	120	129			0.15	0.15	
1100	1800	"	15	25	OFF	112	115	115	110	116	116	121	130			0.15	0.4	
1115	1800	"	15	25	OFF	114	116	116	110	117	118	122	131			0.15	0.35	
1130	1800	"	15	25	OFF	117	120	120	113	120	121	124	134			0.15	0.4	
1145	1800	"	16	25	OFF	120	122	122	114	122	123	126	136			0.15	0.4	
1200	1800	"	16	25	OFF	122	123	123	116	123	124	127	136			0.15	0.4	

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ORC NO.

SERIAL NO.

H 8

DATA MUST BE ACTUAL, NOT RATED VALUES; IF NOT MEASURED, LEAVE BLANK

SHEET NO. ETL-2

DATE 5-16-77 STARTED UNIT C910 ORDER NO. 489254-1

SIGNED

SERIAL NO. 121680

UNIT TEMPERATURE DATA

(Always accompany with P.C.C. Sheet No. ETL-1)

TIME	SPEED ~~HSS~~ LSS	INPUT LOAD	OIL FLOW GPM	OIL PRES. PSI	COOLER			6	7	BEARINGS (Label)								REMARKS
					WATER INLET	OIL 5 INLET	OIL 6 OUTLET	SUMP	HOUSING	LS In 1	LS Out 2	HS In 3	HS Out 4	5	6	LS V	HS V	
0930	1800	SPIN TEST	13	25	OFF	84	92	92	85	91	100	100	91			0.4	0.15	
0945	1800	"	13	25	OFF	93	97	97	92	99	106	107	100			0.4	0.15	*
1000	1800	"	14	25	OFF	97	101	101	96	102	104	111	121			0.4	0.15	REPAIR NO WIRE
1015	1800	"	14	25	OFF	102	106	104	99	107	107	113	123			0.3	0.15	
1030	1800	"	14	25	OFF	108	111	111	103	111	110	117	126			0.35	0.15	
1045	1800	"	14	25	OFF	110	113	113	106	114	114	120	129			0.5	0.15	

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SHEET NO. ETL-2

ORC NO.

SERIAL NO.

H 9

DATE 5-4-77　　　　GEAR SET No. 2　　　　ORDER NO. 4D12338-1

SIGNED J. Hundley　　　　**UNIT TEMPERATURE DATA**　　　　SERIAL NO. 121680

(Always accompany with P.G.C. Sheet No. ETL-1)

STARTED 0540

TIME	SPEED HSS	INPUT LOAD	OIL FLOW GPM	OIL PRES. PSI	COOLER WATER INLET	COOLER OIL INLET	COOLER OIL OUTLET	SUMP	HOUSING	BEARINGS (Label) HS THRU 1	HS BLD 2	LS THRU 3	LS BLD 4	5	6	VIBRATIONS LSS 7	HSS 8	REMARKS
0900	3000	SPIN TEST	-	25	OFF	86	87	87	79	92	100	79	88			.3	.1	
0915	3000	11	-	25	OFF	89	92	92	85	96	103	80	92			.3	.1	
0930	3000	11	-	25	OFF	95	97	97	90	101	107	81	97			.3	.1	
0945	3000	11	-	25	OFF	100	103	103	94	105	111	103	102			.3	.15	
1000	3000	11	-	25	OFF	103	106	106	96	108	113	106	105			.3	.15	
1015	3000	11	-	25	OFF	105	107	107	99	110	115	108	107			.3	.15	
1030	3000	11	-	25	OFF	107	108	108	101	112	117	111	108			.3	.15	
1045	3000	11	-	25	OFF	109	111	111	102	114	119	112	110			.3	.15	
1100	3000	11	-	25	OFF	112	113	113	103	115	120	114	112			.3	.15	
1115	3000	11	-	25	OFF	113	114	114	106	117	122	116	114			.3	.15	
1130	3000	11	-	25	OFF	115	116	116	107	118	124	118	116			.3	.15	
1145	3000	11	-	25	OFF	116	116	116	108	119	125	119	117			.3	.15	

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SHEET NO. ETL-2

ORD' NO.

SERIAL NO.

H 10

DATE

SIGNED Rue

Set # 3

UNIT TEMPERATURE DATA

(Always accompany with P.G.C. Sheet No. ETL-1)

ORDER NO. 489254-

SERIAL NO. 121680

TIME	SPEED HSS	INPUT LOAD	OIL FLOW GPM	OIL PRES. PSI	COOLER WATER INLET	COOLER #5 OIL INLET	COOLER #4 OIL OUTLET	#6 SUMP	Dry HOUSING	BEARINGS (Label) HST 1	MB 2	LSR 3	LST 4	5	6	HT 7	LST 8	REMARKS
145	5000	—		25	off	93	110	10?	88	112	132	109	99			.25	.5	
200	5000	—		25	off	100	105	105	98	117	126	107	107			.25	.5	
215	5000	—		25	off	109	113	112	98	123	132	115	114			.25	.5	
230	5000	—		25	off	112	116	116	104	125	134	118	117			.25	.5	
245	5000	—		25	off	117	121	121	103	128	137	122	121			.25	.5	
300	5000	—		25	off	122	125	125	107	132	141	[illegible]	125			.25	.5	
315	5000	—		25	on	123	127	127	108	133	142	127	126			.25	.5	
330	5000	—		25	on	120	124	124	107	132	140	126	124			.25	.5	
345	5000	—		25	on	120	127	127	110	133	142	125	127			.25	.45	
400	5000	—		25	on	120	122	127	110	133	142	125	126			.25	.45	
415	5000	—		25	on	120	123	127	110	133	142	125	126			.25	.45	
430	5000	—		25	on	120	126	126	110	133	142	128	126			.25	.45	

DATA MUST BE ACTUAL, NOT RATED VALUES; IF NOT MEASURED, LEAVE BLANK

SHEET NO. ETL-2B

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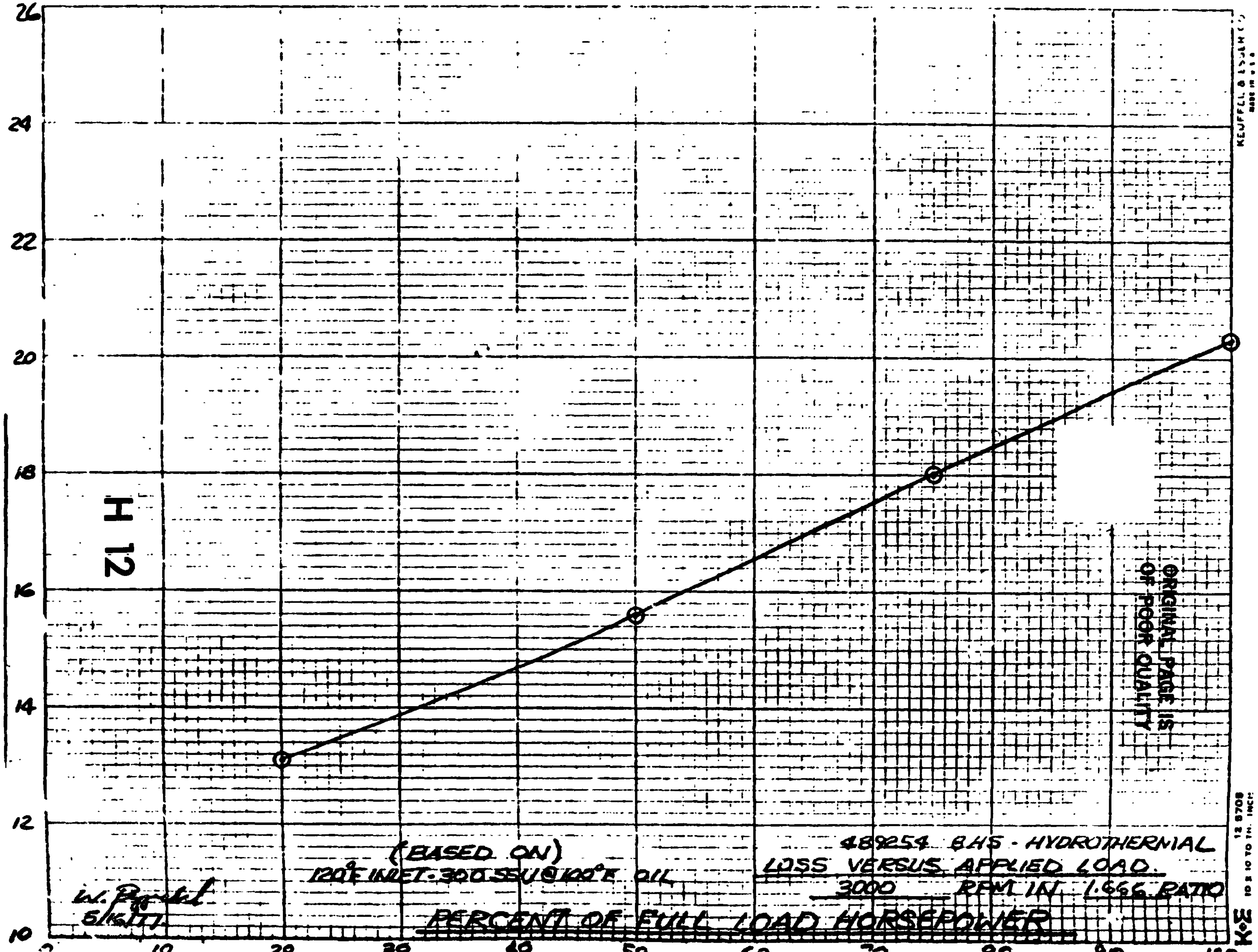
ORD. NO.

SERIAL NO.



26
24
22
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18
16
14
12
10
0
10
20
30
40
50
60
70
80
90
100
(BASED ON)
120°F INLET-300 SSU@100°F OIL
489254 BHS - HYDROTHERNIAL
LOSS VERSUS APPLIED LOAD.
3000 RPM IN 1.666 RATIO
PERCENT OF FULL LOAD HORSEPOWER
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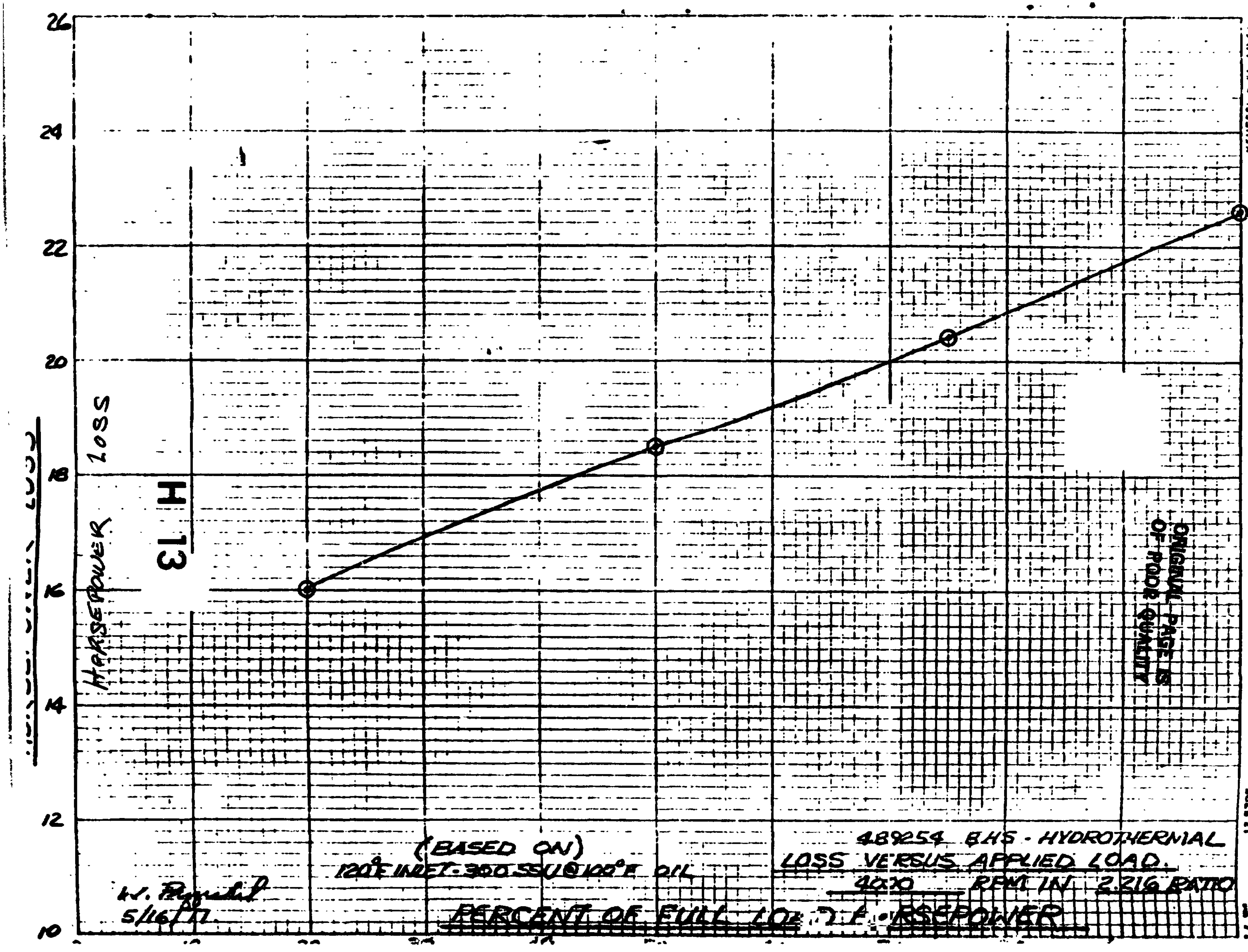
H 12



489254 BHS - HYDROTHERMAL
LOSS VERSUS APPLIED LOAD.
4000 RPM IN 2.216 RATIO
(BASED ON)
120°F INLET - 300 SSU @ 100°F OIL
PERCENT OF FULL LOAD HORSEPOWER
HORSEPOWER LOSS
10
12
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26
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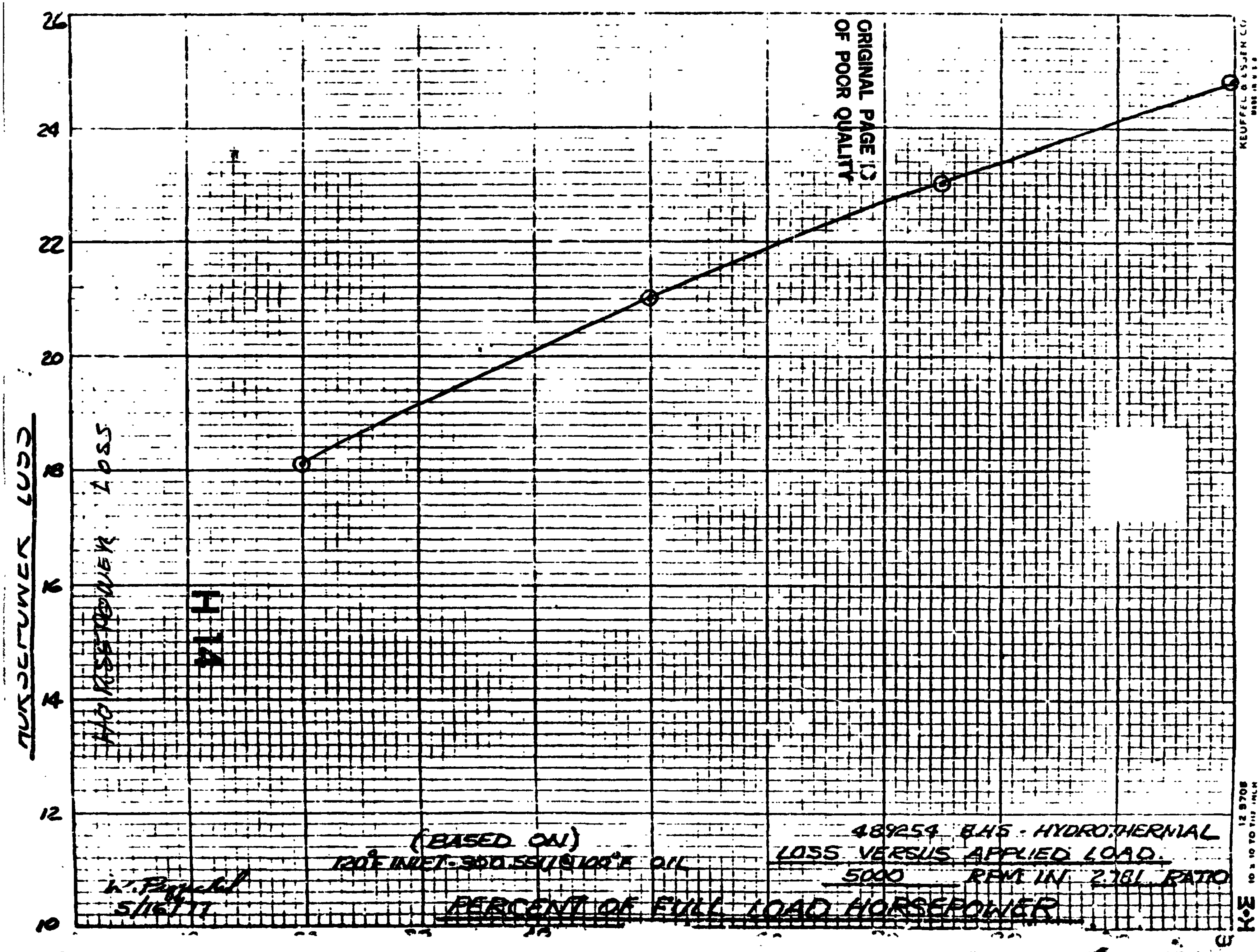
W. [illegible]
5/16/77

H 13



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489254 BHS - HYDROTHERMAL LOSS VERSUS APPLIED LOAD.
5000 RPM IN 2.781 RATIO
(BASED ON) 120°F INLET-300 SSU@100°F OIL
PERCENT OF FULL LOAD HORSEPOWER
HORSEPOWER LOSS
26
24
22
20
18
16
14
12
10
H 14
5/16/77
KEUFFEL & ESSER CO.
K+E

Combining Advanced Design with Proven Performance

RELATIONSHIPS OF SPEED, CAPACITY, PRESSURE, POWER CONSUMPTION

Table "A" below shows the capacity and suggested driving motor size for different speeds and pressures. These figures are based upon pumping a liquid of about 200 SSU viscosity with a 15″ maximum vacuum. While Tuthill Series C pumps will develop as high as 27″ of vacuum, it is sound engineering to reduce the vacuum to a minimum.

The speed of the pump must be reduced when handling liquids of high viscosity, and the size of lines increased to prevent cavitation, loss of capacity and high power requirements. For typical performance with liquids of varying viscosities kindly see chart "B" below. For speeds above 1800 rpm and fluid temperatures above 200° F, consult factory.

PUMP SPEED	1800 RPM										1200 RPM									
OPERATING	10		50		100		200		400		10		50		100		200		400	
PRESSURE PSI / PUMP SIZE	GPM	HP	GPM	HP	GPM	HP	GPM	HP	GPM	HP	GPM	HP	GPM	HP	GPM	HP	GPM	HP	GPM	HP
1	3.2	¼	3.1	⅓	2.7	½					2.1	¼	2	¼	1.9	⅓				
2	9	½	8	¾	7	1½	6½	2	5	3	6½	⅓	6	½	5½	¾	5	1½	4½	2
3	18	1	17	1½	16	3	15	5	12½	7½	12	½	11½	1	11	1½	10	3	8	5
4	37	1½	36	3	35	5	33	7½	29	15	24	1	23½	1½	23	3	21	5	17	7½
5	62	3	61	5	60	7½	54	10	50	20	40	1½	39	3	38	5	35	7½	31	15
6	84	5	83	7½	82	10	80	15	78	25	56	3	55	5	54	7½	50	10	46	20
7											123	5	120	10	115	15	99	20		
8											223	10	220	15	203	25	176	40		

H.P. FOR MAIN LUBE OIL PUMP

BASED ON PUMPING LIQUIDS OF 200 SSU VISCOSITY

RPM		100				300				600				900				1200				1800			
PRESSURE		50-PSI		100-PSI		50-PSI		100-PSI		50-PSI		100-PSI		50-PSI		100-PSI		50-PSI		100-PSI		50-PSI		100-PSI	
PUMP MODEL	VISCOSITY SSU	GPM	HP	GPM	HP	GPM	HP	GPM	HP	GPM	HP	GPM	HP	GPM	HP	GPM	HP	GPM	HP	GPM	HP	GPM	HP	GPM	HP
2C	500					1.3	⅛	1.2	¼	2.4	¼	2.0	⅓	4.0	⅓	3.3	½	5.3	½	4.5	¾	8.4	1	7.5	1½
1″	1,000					1.6	¼	1.5	⅓	3.0	¼	2.8	½	4.5	½	3.8	¾	6.0	¾	5.8	1	9.2	1	9.0	1½
	5,000					1.6	¼	1.5	⅓	3.2	¾	2.8	¾	4.6	1	4.2	1½	6.3	1½	5.9	1½	9.3	2	9.0	2
ports	10,000	.5	⅛	.5	⅙	1.6	⅓	1.5	½	3.2	¾	2.8	¾	4.9	1	4.7	1½								
	25,000	.5	¼	.5	¼	1.6	½	1.5	¾																
3C	500					2.9	¼	2.7	⅓	5.8	½	5.7	¾	8.9	1	8.5	1½	11.9	1½	11.5	2	17.5	2	16.5	3
1¼″	1,000					3.0	¼	2.9	½	6.0	¾	5.9	1	9.0	1	8.3	1½	12.0	1½	11.8	2	18.0	2	17.0	3
	5,000					3.0	½	2.9	¾	6.0	1	5.9	1½	9.1	1½	8.9	2	12.1	2	11.9	3	18.2	3	17.5	5
ports	10,000	1.0	¼	.9	¼	3.0	¾	3.0	¾	6.0	1½	5.9	1½	9.1	2	9.0	2								
	25,000	1.0	⅓	.9	½	3.0	¾	3.0	1																
4C	500					5.8	⅓	5.5	½	11.8	1	11.5	1½	17.8	1½	17.5	2	22.8	2	22.5	3	36.2	5	36.0	5
1½″	1,000					5.9	⅓	5.7	¾	11.9	1	11.7	1½	18.0	2	17.8	3	23.0	3	22.8	5	36.5	5	36.3	5
	5,000					6.0	½	5.8	1	12.0	2	11.8	2	18.0	3	17.8	5	23.0	5	22.8	5	37.0	7½	36.7	7½
ports	10,000	1.9	¼	1.8	⅓	6.1	¾	6.0	1½	12.0	2	11.8	3	18.0	3	17.8	5	23.0	5	22.8	5				
	25,000	1.9	⅓	1.8	½	6.1	1	6.0	1½																
5C	500					9.8	½	9	1	20.0	1½	19.8	2	30.4	3	30.2	5	39	5	38.4	5	60.5	5	60	7½
1½″	1,000					10.0	½	9.5	1	20.2	1½	20.0	3	30.6	3	30.4	5	39.5	5	39.0	5	61	7½	60.5	7½
	5,000					10.3	1	10.0	1½	20.5	2	20.4	3	30.8	5	30.6	5	39.7	5	39.5	7½	61.2	7½	60.8	10
ports	10,000	3.1	⅓	3.0	½	10.3	1	10.0	1½	20.5	2	20.4	3	30.8	5	30.6	5								
	25,000	3.1	½	3.0	¾	10.3	1½	10.0	2																
6C	500					13.5	¾	13.0	1	27.0	2	26.5	3	40.5	5	40.0	5	54.5	5	54.0	7½	83.0	7½	82.0	10
2″	1,000					13.6	¾	13.2	1½	27.4	2	27.0	3	40.8	5	40.3	5	55.0	5	54.5	7½	83.7	7½	83.2	10
	5,000					13.8	1	13.5	1½	27.8	3	27.5	3	41.0	5	40.5	7½	55.2	7½	54.7	10	64.0	10	83.5	15
ports	10,000	4.6	⅓	4.5	½	13.8	2	13.5	2	27.8	5	27.5	5	41.0	7½	40.5	7½	55.2	[illegible]	54.7	10				
	25,000	4.6	½	4.5	¾	13.8	2	13.5	3																

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TEST REPORT

ALTERNATOR

Manufacturer	Kato Engineering Co.
Buyer's P.O.#	1UE12- R3454A
Specification #	
Buyer's Serial #	
Manufacturer's Ser. #	S/N 74526

ADMINISTRATIVE DATA

Testing Organization ____________ KATO ENGINEERING CO.

Test Performed By ______________ (1) C. LEIFERMAN

(2) J. MORTZ

(3) ____________

(4) ____________

Test Performed On ______________ NOV 1976
(Month and Year)

I hereby certify that to the best of my knowledge all tests were performed in accordance with test specifications in ____________ ____________ and true data representing these tests is contained in this report.

[signature]
Signature and Title

KATO ENGINEERING COMPANY
Mankato, Minn.

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LIST OF SYMBOLS

ACV	Generator output voltage
ACI	Generator output current
KVA	Kilovolt-amperes
KW	Power output or input in kilowatts
PF	Power Factor
GFV	DC voltage generator field
GFI	Generator field amps
V_{rp}	Rated phase voltage
I_{rp}	Rated phase current
i	Ammeter reading
L-L	Line to Line
L-N	Line to Neutral
RPM	Revolutions per minute
Ω	Ohms
Lbs.	Pounds
Ft.	Feet
Dyn	Dynamometer
CT	Current Transformer
X_d	Direct axis synchronous reactance
X'_d	Direct asix transient reactance
X''_d	Direct axis subtransient reactance
SCR	Short Circuit Ratio
X_2	Negative sequence reactance
X_o	Zero sequence reactance
MFI	Motor Field Current
MFV	Motor Field Volts
Motor EFI	Motor exciter field current
Motor EFV	Motor Exciter field volts
F_{nl}	Frequency no load
F_{fl}	Frequency full load
V_{nl}	Voltage no load
V_{fl}	Voltage @ full load
I_{fl}	Line current @ full load
1-2,2-3,3-1	Three phase terminal to terminal readings
1-2-3	Three phase line currents
Vave	Average of the three phase voltages
Iave	Average of the three line currents
CC res	Cross current resistor
CC Comp	Cross current compensation
EFI (Gen.)	Exciter field amps
EFV (Gen.)	Exciter field volts
NA	Not applicable
CWFDE	Clockwise facing drive end
CCWFDE	Counterclockwise facing drive end
EFF	Efficiency
T'do	Direct axis transient open circuit time constant
T'd	Direct axis transient short circuit time constant
W&F	Windage & Friction
CL	Core loss
SLL	Stray load loss

KATO ENGINEERING COMPANY

SYNCHRONOUS MACHINE COMMERCIAL TEST

KW	KVA	P.F.	RPM	PHASE	FREQ.	VOLTS	AMPS	SERIAL NO.	UNIT
1000	1250	0.8	1800	3Ø	60	480	1509	74526	1

CUSTOMER: Sweihart Electric Co Inc DATE: 11/23/76

TESTED BY: L. Hewitt PD Kralovec

RESISTANCE:

ARM 1-2 0.00293 Ω@23.8°C.	GEN FLD 1.366 Ω@23.8°C.	CODE 4P6-2175
ARM 2-3 0.00293 Ω@23.8°C.	EXC FLD 11.99 Ω@23.8°C.	TYPE 18856
ARM 3-1 0.00293 Ω@23.8°C.	PM FLD ——— Ω@ °C.	MODEL 1000E29E

SATURATION CURVE

ACV	ACI	KVA	KW	P.F.		DCV	EFI	HZ
696	0					58.7	5.00	60
679	0					47.3	4.00	60
646	0					35.7	3.00	60
588	0					23.8	2.00	60
528	0					16.8	1.43	60
480	0					13.3	1.16	60
456	0					12.2	1.07	60
384	0					8.9	.77	60
240	0					4.9	.442	60
480	1509	1250	—	0.0		37.6	3.17	60
650	0	———	———	———		37.6	3.17	60

EXCITATION	SEP
EXC. POLARITY	F+ -4
RES. VOLT.	39.0
CONNECTED	Δ____ Y____
ROTATION	CW FDE
SEQUENCE	T1-T2-T3
COMM RUNOUT	———
COMMUTATION	Brushless
RADIO SUPPRESSION	———
BEARINGS	OK
MECH. BAL. (P-P)	
DR. END = 0	
OPP. END = 0	

AIR GAP (MINIMUM)

EXCITER	0.034
P.M. FLD.	———

1) NUMBER OF LEADS 4
2) CONNECTED FOR 4 LEADS WHEN SHIPPED.
3) VOLTAGE REGULATOR MODEL ——— S/N ———
4) VOLTAGE ADJUST RANGE: ——— TO ——— VAC

DIELECTRIC STRENGTH

GEN ARM	VOLT
GEN FLD	VOLT
EXC ARM	VOLT
EXC FLD	VOLT
PM FLD	VOLT

INSULATION RESISTANCE

GEN ARM	MEGΩ
GEN FLD	MEGΩ
EXC ARM	MEGΩ
EXC FLD	MEGΩ
PM FLD	MEGΩ

REMARKS

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PM GENERATOR

VOLT	AMP
	—
	—
	—

I-4

PH	ACV			ACI	
$T_{1\text{-}2}$	480	1-N	277	1	1509
$T_{2\text{-}3}$	480	2-N	277	2	1509
$T_{3\text{-}1}$	480	3-N	277	3	1509

KATO ENGINEERING COMPANY

SYNCHRONOUS MACHINE COMMERCIAL TEST

KW	KVA	P.F.	RPM	PHASE	FREQ.	VOLTS	AMPS	SERIAL NO.	UNIT
1000	1250	.8	1800	3Ø	60	277/480	1506	74526	1

CUSTOMER: SWEINHART ELEC. CO DATE: 11-30-76

TESTED BY: J. MROTZ - K. WITBECK - C. LEIFERMAN.

RESISTANCE:

ARM 1-2 0.00293 Ω@23.8°C.	GEN FLD 1.366 Ω@23.8°C.	CODE	4P6-2175
ARM 2-3 0.00293 Ω@23.8°C.	EXC FLD 11.44 Ω@23.8°C.	TYPE	18856
ARM 3-1 0.00293 Ω@23.8°C.	PM FLD Ω@ °C.	MODEL	1000 ER9E

SATURATION CURVE

ACV	ACI	KVA	KW	P.F.		DCV	EFI	HZ

EXCITATION	REG.
EXC. POLARITY	F2 = +
RES. VOLT.	
CONNECTED	Δ ___ Y ✓
ROTATION	CW FOE
SEQUENCE	
COMM RUNOUT	BRUSHLESS
COMMUTATION	—
RADIO SUPPRESSION	—
BEARINGS	
MECH. BAL: (P-P)	
DR. END = 0 .	
OPP. END = 0 .	

AIR GAP (MINIMUM)

EXCITER	OVER 0.024"
P.M. FLD.	—

DIELECTRIC STRENGTH

GEN ARM	2000 VOLT
GEN FLD	1500 VOLT
EXC ARM	1500 VOLT
EXC FLD	1500 VOLT
PM FLD	— VOLT

1) NUMBER OF LEADS 4
2) CONNECTED FOR 4 LEADS WHEN SHIPPED.
3) VOLTAGE REGULATOR MODEL SR4 S/N ______
4) VOLTAGE ADJUST RANGE: ______ TO ______ VAC

INSULATION RESISTANCE

GEN ARM	OVER 100 MEGΩ
GEN FLD	OVER 100 MEGΩ
EXC ARM	OVER 10 MEGΩ
EXC FLD	OVER 100 MEGΩ
PM FLD	--- MEGΩ

REMARKS

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GENERATOR

VOLT	AMP

I-5

PH	ACV			ACI	
T_{1-2}	480.0	1-N	277.0	1	1506
T_{2-3}	480	2-N	277	2	1506
T_{3-1}	480	3-N	277	3	1506

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TEST RECORD

KATO ENGINEERING CO.

MANKATO, MINNESOTA U.S.A.

SERIAL NO. 74526-1
MODEL 1000 EP9E
TYPE NO. 10250
PHASE 3
KVA 1250 KW 1000
VOLTS 480
FREQ. 60 RPM 1700
TEMP. RISE
ROTATION CW FDE
EXCITATION

CUSTOMER Sweinhart Electric
P.O. OR CONTRACT NO.

TEST Efficiency
Direct Loading
Self Excited
Repeat Test

DATE 11-30-76
SPEC.
METHOD
TESTED BY J. Mrotz
D. Hoel
C. Leiferman
GOV'T. INSP.

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INST. / READ NO. / UNITS / FACTOR	TIME	VOLTS	AMPS	HZ	PF	GFI	GFV	EFV	EFI	W1 WATTS	W2 WATTS	CT 500/5	TOTAL KW	RPM	EMBEDDED TEMP DETECTORS TD-1	TD-2	°C	GROSS LBS	DRIVE LOSS LBS	NET LBS	ARM FT
[illegible]	*	480.0	120	59.1	1.0	26.4	37.6	14.4	1.25	496	504	100	100	1775	113.4	114.2	40	157	135.8	73.6	[illegible]
[illegible]		480.0	240	58.1	1.0	27.8	39.5	15.8	1.34	998	1002	100	200	1745	113.8	114.9	40	272.5	233.7	85.6	[illegible]
[illegible]		480.0	150	59.1	0.8	28.8	41.0	15.9	1.36	306	734	100	104	1775	114.1	115.2	40	160	138.4	72.1	[illegible]
[illegible]		480.0	300	58.0	0.8	46.2	32.2	18.0	1.55	582	1442	100	202.4	1741	114.5	115.7	40	276.5	236.6	85.5	3.5
[illegible]		480.0	150	59.1	[illegible]	66.5	95.2	37.2	3.18	1023	-802	100	22.1	1773	114.9	115.5	40	161.7	139.8		[illegible]
312.5	Kva	480.0	376	58.7	0.0	53.8	35.4	18.6	1.69	240	-198		4.2	1793	117.6	118.5	47	58			3.5
—	—	480.0	0	—	—	38.4	26.0	14.5	1.22	—	—			—				43.5			
312.5	Kva	480.0	376	57.8	0.66	50.5	34.8	19.5	1.68	422	78			1737				391.0			3.5
		480.0	0	—	—	38.4	26.0	14.5	1.22	—	—							43.5			

VOLTAGE ADJUST RANGE = 392.0 TO 525.0 VAC

REMARKS

*SAMPLE CALCULATION : WATTS-INPUT $= \frac{FLN}{5252} \times 746 = \frac{(157-3.15) \times 3.5 \times 1775}{5252} \times 746 = 135.8$

% EFFICIENCY $= \frac{P_{OUT}}{P_{IN}} = \frac{100}{135.8} = 73.6\%$

WHERE DRIVE LOSS = 3.15 LBS @ 3.5 FT

SHEET 1 OF 3

SERIAL NO. 74526-1
MODEL 1000 FDYE
TYPE NO. 1885G
PHASE 3
KVA 1250 KW 1000
VOLTS 480
FREQ. 60 RPM 1800
TEMP. RISE
ROTATION C.C.W. F.D.E.
EXCITATION

TEST RECORD
KATO ENGINEERING CO.
MANKATO, MINNESOTA U.S.A.

CUSTOMER Swinehart Electric
P.O. OR CONTRACT NO.
TEST Efficiency Test

DATE 11-30-76
SPEC.
METHOD
TESTED BY J. MROTZ
D. HOEL
C. LEIFERMAN
GOV'T. INSP.

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OPEN CIRCUIT CORE LOSS. SEGREGATED LOSSES METHOD

REPEAT TEST

INST. / TIME %	ACV	ACT	HZ	GFV	GFT	DRIVE: CROSS LBS	LOSS LBS	NET LBS	LEVER ARM FT	DYN RPM	F&W: CL+FW WATTS	FW WATTS	CL WATTS
FRICTION & WINDAGE TEST													
	0	0	59.82	0	0	33.5	3.15	30.35	3.5	1795		27.1	
* OPEN CIRCUIT CORE LOSS TEST													
125	[illegible]	0	59.78	58.5	44.0	47.4	3.15	44.3	3.5	1794	39.51	27.1	12.41
115	[illegible]	0	59.78	46.0	32.0	45.3	3.15	42.2	3.5	1794	37.64	27.1	10.51
105	504	0	59.78	41.5	29.0	44.3	3.15	41.2	3.5	1794	36.75	27.1	9.65
A 100	480	0	59.79	37.0	26.0	43.0	3.15	39.9	3.5	1794	35.59	27.1	8.49
95	456	0	59.80	33.5	23.5	42.0	3.15	38.9	3.5	1795	34.71	27.1	7.61
90	432	0	59.80	31.0	21.5	41.1	3.15	38.0	3.5	1795	33.91	27.1	6.81
80	3[illegible]1	0	59.81	27.0	19.0	39.9	3.15	36.8	3.5	1795	32.84	27.1	5.74
70	[illegible]	0	59.81	22.0	15.5	38.3	3.15	35.2	3.5	1795	31.41	27.1	4.31
60	[illegible]	0	59.82	18.5	13.0	37.3	3.15	34.2	3.5	1795	30.52	27.1	3.43
	260	0	59.82	16.5	11.5	36.7	3.15	33.6	3.5	1795	30.00	27.1	2.90

REMARKS: [illegible] FIELD SEPARATELY EXCITED
WHERE F&W = FRICTION & WINDAGE
[illegible] = CORE LOSS

SHEET 2 OF 3

A CORE LOSS @ RATED VOLTAGE

17

A

$K_c = \frac{.00273}{2}(1.64) = .00[illegible]$

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74526-1	TEST RECORD	DATE	11-30-76
[illegible]	KATO ENGINEERING CO.	SPEC.	
3	MANKATO, MINNESOTA S.A.	METHOD	
KW 1000	CUSTOMER S[illegible] Electric	TESTED BY	J. MROTZ / C. LEIFERMAN
RPM 1800	P.O. OR CONTRACT NO.		
RISE			
[illegible]TATION			
EXCITATION [illegible]	TEST Efficiency	GOV'T. INSP.	

STRAY LOAD LOSS TEST — REPEAT TEST — SEGREGATED LOSSES METHOD

18

INST. / FACTOR	ACI	ACV	ACI	HZ		GFV	GFI		Ohms TD1	TD-4	°C		Gross LBS	Drive Loss LBS	Net LBS	Lever Arm FT	Dyna RPM	F&W SLL Watts	F&W Watts	I^2R Watts	SLL Watts	AVG. AMB. TEMP.
							* STRAY LOAD LOSS TEST															
	150	0	2255	—		66.5	46.6		112.2	118.4			66.4	3.15	63.25	3.5	1790	56.29	27.1	23.78	5578	
	125	0	[illegible]	—		55.2	38.3		112.8	120.2			57.2	3.15	54.05	3.5	1793	48.15	27.1	16.53	4520	
	100	0	1504	—		44.1	30.7		[illegible]8.5	122.4			49.2	3.15	46.05	3.5	1793	41.05	27.1	10.58	3370	
	75	0	1123	—		33.0	22.9		118.6	122.6			42.4	3.15	39.25	3.5	1794	35.00	27.1	5.95	1950	
	50	0	753	—		21.9	15.2		118.4	121.9			37.5	3.15	34.35	3.5	1795	20.65	27.1	2.64	910	
			3.15 LBS @ 3.5 FT			~~DRIVE LOSS~~									USE ORIGINAL TEST DATA							
	33	0	500	—		15.0	10.3		117.5	120.4			35.2	3.15	32.05	3.5	1795	28.78	27.1	1.17	510	
	16	0	240	—		8.1	5.8		112.1	112.9			33.9	3.15	30.75	3.5	179[illegible]	27.[illegible]	27.1	.27	70	
	8	0	120	—		4.0	2.7		112.3	117.9			33.7	3.15	30.55	3.5	1795	27.26	27.1	.07	90	

REMARKS
* MAIN GEN FIELD SEPARATELY EXCITED
WHERE I^2R = STATOR COPPER LOSS
Δ REMOVE OR DISCONNECT GEN FROM DYNA AND OPERATE DYNA AT RATED SPEED RECORD LBS & FT, RPM

SHEET 3 OF 3

100 % LOAD

EFFICIENCY CALCULATIONS

KATO ENGINEERING CO.

Mankato, Minnesota

S/N 74526
MODEL 1000 ER9E
MIL-STD 705
METHOD 115
DATE 11-30-77

A. Friction & Windage Loss (No Excitation)

Watts $= \frac{F\ L\ N}{5252} \times 746$

Where: F = NET FORCE IN LBS.

L = LEVER ARM IN FT.

N = SPEED OF DYNOMOMETER IN RPM

$= \frac{(30.35)(3.5)(1795)}{5252} \times 746$

= 27083 WATTS

B. Core Loss + Windage and Friction (@ Rated Voltage)

Watts $= \frac{F\ L\ N}{5252} \times 746$

$= \frac{(39.9)(3.5)(1794)}{5252} \times 746$

= 35585 WATTS

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Core Loss B-A

= 35585 - 27083

= 8502 WATTS

C. Armature Copper Loss (Stray Load Loss Test)

Watts $= I^2_{arm} \times R \times 3$

Where: I = RATED ARMATURE CURRENT

R = ARMATURE RESISTANCE PER PHASE AT TIME OF THE STRAY LOAD LOSS TEST.

$= (1504)^2\ (.00155)\ (3)$

= 10518 WATTS

D. Stray Load Loss + I^2R Loss + Friction & Windage (@ Rated Armature Current)

Watts $= \frac{F\ L\ N}{5252} \times 746$

$= \frac{(46.05)(3.5)(1793)}{5252} \times 746$

= 41048 WATTS

Stray Load Loss = D-(A + C)

= 41048 - (27083 + 10518)

= 3447 WATTS

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100 % LOAD

EFFICIENCY CALCULATIONS

KATO ENGINEERING CO.

Mankato, Minnesota

S/N 74526
MODEL 1000 ER9E
MIL-STD-705
METHOD 415.0
DATE

E. Armature I^2R Loss

Watts = $I^2_{arm} \times R_{75} \times 3$

= $(1504)^2$ (.001755) (3)

= 11,912 Watts

Where: I_{arm} = RATED ARMATURE CURRENT

R_{75} = RESISTANCE PER PHASE Corrected to 75°c

$R_{75} = \frac{234.5 + 75}{234.5 + 23.8} \times \frac{.00293}{2}$ ohms

$= \frac{309.5}{258.3} \times .001465$ ohms

= .001755 ohms

F. Generator Field $I^2 \times R$ Loss

WATTS = $(60)^2 \times 1.636$

= 5892 WATTS

Where: I_f = FIELD CURRENT AT RATED LOAD

R_{75} = RESISTANCE OF THE FIELD CORRECTED TO 75°c

$R_{75} = \frac{234.5 + 75}{234.5 + 23.8} \times 1.366$ ohms

$= \frac{309.5}{258.3} \times 1.366$ ohms

= 1.636 ohms

Total Losses (Watts)

1. Friction & Windage Loss —— 27083
2. Core Loss —— 8502
3. Stray Load Loss —— 3447
4. Armature I^2R Loss —— 11912
5. Field I^2R Loss —— 5892
6. EXCITER LOSSES —— 800

57636

Efficiency:

$\%\ \text{Eff.} = 100 - \frac{\text{Losses} \times 100}{\text{Output} + \text{Losses}}$

$= 100 - \frac{(57636)\ (100)}{1,000,000 + 57636}$

= 100 - 5.449

% Eff. = 94.55

75 % LOAD

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EFFICIENCY CALCULATIONS

KATO ENGINEERING CO.

Mankato, Minnesota

S/N 74526
MODEL 1000 ER9E
MIL-STD 705
METHOD 115.0
DATE 11-30-77

A. Friction & Windage Loss (No Excitation)

Watts = $\frac{F\ L\ N}{5252}$ x 746

= $\frac{\_\_\_\_\_\_}{5252}$ x 746

= 27083 WATTS

Where: F = NET FORCE IN LBS.

L = LEVER ARM IN FT.

N = SPEED OF DYNOMOMETER IN RPM

B. Core Loss + Windage and Friction (@ Rated Voltage)

Watts = $\frac{F\ L\ N}{5252}$ x 746

= ______ x 746

= ______ WATTS

Core Loss B-A

= ____ - ____

= 8502 WATTS

C. Armature Copper Loss (Stray Load Loss Test)

Watts = I^2_{arm} x R x 3

= ($)^2$ ( ) (3)

= ______ WATTS

Where: I = RATED ARMATURE CURRENT

R = ARMATURE RESISTANCE PER PHASE AT TIME OF THE STRAY LOAD LOSS TEST.

D. Stray Load Loss + I^2R Loss + Friction & Windage (@ Rated Armature Current)

Watts = $\frac{F\ L\ N}{5252}$ x 746

= $\frac{\_\_\_\_\_\_}{5252}$ x 746

= ______ WATTS

Stray Load Loss = D-(A + C)

$(3447)\left(\frac{3}{4}\right)^2$ = 1939 - (— + —)

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75 % LOAD

EFFICIENCY CALCULATIONS

KATO ENGINEERING CO.

Mankato, Minnesota

S/N
MODEL
MIL-STD-705
METHOD 415.0
DATE

E. Armature I^2R Loss

Watts = $I^2_{arm} \times R_{75} \times 3$

= ( )^2 ( ) (3)

$(11,912)\left(\frac{3}{4}\right)^2 = 6700$ Watts

Where: I_{arm} = RATED ARMATURE CURRENT

R_{75} = RESISTANCE PER PHASE Corrected to 75°c

R_{75} = $\frac{234.5 + 75}{234.5 +}$ X ohms

= $\frac{309.5}{}$ X ohms

= ohms

F. Generator Field $I^2 \times R$ Loss

$I_{FLD} @ \frac{3}{4} LOAD = (I_{FLD\ FL} - I_{NL})\frac{3}{4} + I_{NL}$

$= (60 - 27.2)\frac{3}{4} + 27.2$

$= 51.8$

WATTS $= I^2 R$

$= (51.8)^2 (1.636)$

$= 4390$

Where: I_f = FIELD CURRENT AT RATED LOAD

R_{75} = RESISTANCE OF THE FIELD CORRECTED TO 75°c

R_{75} = $\frac{234.5 + 75}{234.5 +}$ X ohms

= $\frac{309.5}{}$ X ohms

= ohms

Total Losses (Watts)

1. Friction & Windage Loss ——— 27083
2. Core Loss ——— 8502
3. Stray Load Loss ——— 1939
4. Armature I^2R Loss ——— 6700
5. Field I^2R Loss ——— 4390
6. EXCITER ——— 595

49209

Efficiency:

% Eff. = 100 - $\frac{\text{Losses} \times 100}{\text{Output + Losses}}$

= 100 - $\frac{(49209)(100)}{750,000 + 49209}$

= 100 - 6.157

% Eff. = 93.84

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50 % LOAD

EFFICIENCY CALCULATIONS

KATO ENGINEERING CO.

Mankato, Minnesota

S/N 74526
MODEL 1000ER9E
MIL-STD 705
METHOD 115.0
DATE 11-23-76

A. Friction & Windage Loss (No Excitation)

Watts $= \frac{F\ L\ N}{5252} \times 746$

Where: F = NET FORCE IN LBS.

L = LEVER ARM IN FT.

N = SPEED OF DYNOMOMETER IN RPM

$= \frac{\quad}{5252} \times 746$

= 27083 WATTS

B. Core Loss + Windage and Friction (@ Rated Voltage)

Watts $= \frac{F\ L\ N}{5252} \times 746$

= ________ x 746

= ________ WATTS

Core Loss B-A

= ________ - ________

= 8502 WATTS

C. Armature Copper Loss (Stray Load Loss Test)

Watts $= I^2_{arm} \times R \times 3$

Where: I = RATED ARMATURE CURRENT

R = ARMATURE RESISTANCE PER PHASE AT TIME OF THE STRAY LOAD LOSS TEST.

$= (\quad)^2 (\quad) (3)$

= ________ WATTS

D. Stray Load Loss + I^2R Loss + Friction & Windage (@ Rated Armature Current)

Watts $= \frac{F\ L\ N}{5252} \times 746$

$= \frac{\quad}{5252} \times 746$

= ________ WATTS

I-13

Stray Load Loss = D-(A + C)

$(3447)(\frac{1}{2})^2$ = 862 - (________ + ________)

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50 % LOAD
EFFICIENCY CALCULATIONS

KATO ENGINEERING CO.

Mankato, Minnesota

S/N 74526
MODEL 1000 ER9E
MIL-STD-705
METHOD 415.0
DATE 11-30-76

E. Armature I^2R Loss

Watts = $I^2_{arm} \times R_{75} \times 3$

= ( )^2 ( ) (3)

$\left(\frac{1}{2}\right)^2 (11{,}912) = 2978$ Watts

Where: I_{arm} = RATED ARMATURE CURRENT

R_{75} = RESISTANCE PER PHASE Corrected to 75°c

R_{75} = $\frac{234.5 + 75}{234.5 + }$ X ohms

= $\frac{309.5}{}$ X ohms

= ohms

F. Generator Field $I^2 \times R$ Loss

I_{FLD} @ 50% $= (I_{FL} - I_{NL})\frac{1}{2} + I_{NL}$

$= (60 - 27.2)\frac{1}{2} + 27.2$

$= 43.6$

WATTS $= I^2 R$

$= (43.6)^2 \; (1.636)$

$= 3110$

Where: I_f = FIELD CURRENT AT RATED LOAD

R_{75} = RESISTANCE OF THE FIELD CORRECTED TO 75°c

R_{75} = $\frac{234.5 + 75}{234.5 + }$ X ohms

= $\frac{309.5}{}$ X ohms

= ohms

Total Losses (Watts)

1. Friction & Windage Loss	27083
2. Core Loss	8502
3. Stray Load Loss	862
4. Armature I^2R Loss	2978
5. Field I^2R Loss	3110
6 EXCITER LOSS	425
	42960

Efficiency:

% Eff. = 100 - $\frac{\text{Losses} \times 100}{\text{Output} + \text{Losses}}$

= 100 - $\frac{(42960)(100)}{500{,}000 + 42960}$

= 100 - 7.912

% Eff. = 92.08

20 % LOAD

EFFICIENCY CALCULATIONS

KATO ENGINEERING CO.

Mankato, Minnesota

S/N 74625
MODEL 1000 ER9C
MIL-STD 705
METHOD 1.5.0
DATE 11-30-76

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A. Friction & Windage Loss (No Excitation)

$$\text{Watts} = \frac{F\ L\ N}{5252} \times 746$$

Where: F = NET FORCE IN LBS.
L = LEVER ARM IN FT.
N = SPEED OF DYNOMOMETER IN RPM

$= \frac{\text{—}}{5252} \times 746$

= 27083 WATTS

B. Core Loss + Windage and Friction (@ Rated Voltage)

$$\text{Watts} = \frac{F\ L\ N}{5252} \times 746$$

= ______ x 746

= ______ WATTS

Core Loss B-A

= ______ - ______

= 8502 WATTS

C. Armature Copper Loss (Stray Load Loss Test)

Watts = $I^2_{arm} \times R \times 3$

$= (\quad)^2 (\quad) (3)$

= ______ WATTS

Where: I = RATED ARMATURE CURRENT
R = ARMATURE RESISTANCE PER PHASE AT TIME OF THE STRAY LOAD LOSS TEST.

D. Stray Load Loss + I^2R Loss + Friction & Windage (@ Rated Armature Current)

$$\text{Watts} = \frac{F\ L\ N}{5252} \times 746$$

$= \frac{\text{______}}{5252} \times 746$

= ______ WATTS

I-15

Stray Load Loss = D-(A + C)

$(.2)^2(3.447)$ = 138 - (— + —)

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20% LOAD

EFFICIENCY CALCULATIONS

KATO ENGINEERING CO.

Mankato, Minnesota

S/N 74625
MODEL 1000 ER9E
MIL-STD-705
METHOD 415.0
DATE 11-30-76

E. Armature I^2R Loss

Watts = I^2_{arm} X R_{75} X 3

= ( )^2 ( ) (3)

$(.2)^2(11912)$ = 476 Watts

Where: I_{arm} = RATED ARMATURE CURRENT

R_{75} = RESISTANCE PER PHASE Corrected to 75°c

R_{75} = $\frac{234.5 + 75}{234.5 +}$ X ohms

= $\frac{309.5}{}$ X ohms

= ohms

F. Generator Field I^2 X R Loss

$I_{FLD} = (I_{FL} - I_{NL})(.2) + I_{NL}$

$= (60 - 27.2)(.2) + 27.2$

$= 33.76$

WATTS = I^2R

$= (33.76)^2(1.636)$

= WATTS

Where: I_f = FIELD CURRENT AT RATED LOAD

R_{75} = RESISTANCE OF THE FIELD CORRECTED TO 75°c

R_{75} = $\frac{234.5 + 75}{234.5 +}$ X ohms

= $\frac{309.5}{}$ X ohms

= ohms

Total Losses (Watts)

1. Friction & Windage Loss ——— 27083
2. Core Loss ——— 8502
3. Stray Load Loss ——— 138
4. Armature I^2R Loss ——— 476
5. Field I^2R Loss ——— 1865
6. Exciter Loss ——— 224

38288

Efficiency:

% Eff. = 100 - $\frac{\text{Losses x 100}}{\text{Output + Losses}}$

= 100 - $\frac{(38288)\ (100)}{200,000 + 38288}$

= 100 - 16.06

% Eff. = 83.93

116

C-2

10 % LOAD

EFFICIENCY CALCULATIONS

KATO ENGINEERING CO.

Mankato, Minnesota

S/N 74526
MODEL 1000 ES9E
MIL-STD 705
METHOD 1150
DATE 11-30-76

A. Friction & Windage Loss (No Excitation)

Watts $= \frac{F\ L\ N}{5252} \times 746$

Where: F = NET FORCE IN LBS.

L = LEVER ARM IN FT.

N = SPEED OF DYNOMOMETER IN RPM

$= \frac{\_\_\_\_\_\_}{5252} \times 746$

= 27083 WATTS

B. Core Loss + Windage and Friction (@ Rated Voltage)

Watts $= \frac{F\ L\ N}{5252} \times 746$

= ______ x 746

= ______ WATTS

ORIGINAL PAGE IS OF POOR QUALITY

Core Loss B-A

= ______ - ______

= 8502 WATTS

C. Armature Copper Loss (Stray Load Loss Test)

Watts $= I^2_{arm} \times R \times 3$

Where: I = RATED ARMATURE CURRENT

R = ARMATURE RESISTANCE PER PHASE AT TIME OF THE STRAY LOAD LOSS TEST.

$= (\quad)^2 (\quad) (3)$

= ______ WATTS

D. Stray Load Loss + I^2R Loss + Friction & Windage (@ Rated Armature Current)

Watts $= \frac{F\ \ N}{5252} \times 746$

$= \frac{\_\_\_\_\_\_}{5252} \times 746$

= ______ WATTS

Stray Load Loss = D-(A + C)

$(.1)^2(3447)$ = 35 - (— + —)

ORIGINAL PAGE IS OF POOR QUALITY

EFFICIENCY CALCULATIONS

KATO ENGINEERING CO.

Mankato, Minnesota

S/N 74526
MODEL 1000 ER9E
MIL-STD-705
METHOD 415.0
DATE 30 NOV 1976

E. Armature I^2R Loss

Watts = I^2_{arm} X R_{75} X 3

= (   )^2 (   ) (3)

$(.1)^2(11,912)$ = 119 Watts

Where: I_{arm} = RATED ARMATURE CURRENT

R_{75} = RESISTANCE PER PHASE Corrected to 75°c

R_{75} = $\frac{234.5 + 75}{234.5 +}$ X ohms

= $\frac{309.5}{}$ X ohms

= ohms

F. Generator Field I^2 X R Loss

$I_{FLD} = (I_{FL} - I_{NL})(.1) + I_{NL}$

$= (60 - 27.2)(.1) + 27.2$

$= 30.48$

WATTS = I^2R

$= (30.48)^2(1.636)$

= 1520 WATTS

Where: I_f = FIELD CURRENT AT RATED LOAD

R_{75} = RESISTANCE OF THE FIELD CORRECTED TO 75°c

R_{75} = $\frac{234.5 + 75}{234.5 +}$ X ohms

= $\frac{309.5}{}$ X ohms

= ohms

Total Losses (Watts)

1. Friction & Windage Loss ——— 27083
2. Core Loss ——— 8502
3. Stray Load Loss ——— 35
4. Armature I^2R Loss ——— 119
5. Field I^2R Loss ——— 1520
6. EXCITER ——— 188

37442

Efficiency:

% Eff. = 100 - $\frac{\text{Losses x 100}}{\text{Output + Losses}}$

= 100 - $\frac{(37442)(100)}{100,000 + 37442}$

= 100 - 27.24

% Eff. = 72.75

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100 % LOAD (1.0 PF)

EFFICIENCY CALCULATIONS

KATO ENGINEERING CO.

Mankato, Minnesota

S/N 74526
MODEL 1000 ER9E
MIL-STD 705
METHOD 115.0
DATE 30 NOV 1976

A. Friction & Windage Loss (No Excitation)

Watts $= \frac{F\ L\ N}{5252} \times 746$

Where: F = NET FORCE IN LBS.
L = LEVER ARM IN FT.
N = SPEED OF DYNOMOMETER IN RPM

$= \frac{\_\_\_\_\_\_}{5252} \times 746$

= 27083 WATTS

B. Core Loss + Windage and Friction (@ Rated Voltage)

Watts $= \frac{F\ L\ N}{5252} \times 746$

= ______ x 746

= ______ WATTS

Core Loss B-A

= ______ - ______

= 8502 WATTS

C. Armature Copper Loss (Stray Load Loss Test)

Watts $= I^2_{arm} \times R \times 3$

Where: I = RATED ARMATURE CURRENT
R = ARMATURE RESISTANCE PER PHASE AT TIME OF THE STRAY LOAD LOSS TEST.

$= (\quad)^2 (\quad) (3)$

= ______ WATTS

D. Stray Load Loss + I^2R Loss + Friction & Windage (@ Rated Armature Current)

Watts $= \frac{F\ L\ N}{5252} \times 746$

$= \frac{\_\_\_\_\_\_}{5252} \times 746$

= ______ WATTS

Stray Load Loss = D-(A + C)

$\left(\frac{1202}{1504}\right)^2 (3447)$ = 2202 - (____ + ____)

WHERE 1202 = I_{LINE} @ 1000 KW 1.0PF

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100 % LOAD (1.0 PF)

EFFICIENCY CALCULATIONS

KATO ENGINEERING CO.

Mankato, Minnesota

S/N 74526
MODEL 1000 ER9E
MIL-STD-705
METHOD 415.0
DATE 30 NOV 1976

E. Armature I^2R Loss

Watts = I^2_{arm} X R_{75} X 3

= (   )^2 (   ) (3)

$\left(\frac{1202}{1504}\right)^2 (11912)$ = 7608 Watts

Where: I_{arm} = RATED ARMATURE CURRENT

R_{75} = RESISTANCE PER PHASE Corrected to 75°c

R_{75} = $\frac{234.5 + 75}{234.5 +}$ X ohms

= $\frac{309.5}{\quad}$ X ohms

= ohms

F. Generator Field I^2 X R Loss

WATTS = $I^2 R$

$= (37.3)^2 (1.636)$

$= 2276$

Where: I_f = FIELD CURRENT AT RATED LOAD

R_{75} = RESISTANCE OF THE FIELD CORRECTED TO 75°c

R_{75} = $\frac{234.5 + 75}{234.5 +}$ X ohms

= $\frac{309.5}{\quad}$ X ohms

= ohms

Total Losses (Watts)

1. Friction & Windage Loss	27083
2. Core Loss	8502
3. Stray Load Loss	2202
4. Armature I^2R Loss	7608
5. Field I^2R Loss	2276
6. EXCITER	310
	47981

Efficiency:

% Eff. = 100 - $\frac{\text{Losses x 100}}{\text{Output + Losses}}$

= 100 - $\frac{(47981)\ (100)}{1{,}000{,}000 + 47981}$

= 100 - 4.58

% Eff. = 95.4

75 % LOAD 1.0 PF

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EFFICIENCY CALCULATIONS

KATO ENGINEERING CO.

Mankato, Minnesota

S/N 74526
MODEL 1000 ER9E
MIL-STD 705
METHOD 415.0
DATE 30 NOV 1976

A. Friction & Windage Loss (No Excitation)

Watts = $\frac{F\ L\ N}{5252}$ x 746

Where: F = NET FORCE IN LBS.
L = LEVER ARM IN FT.
N = SPEED OF DYNOMOMETER IN RPM

= $\frac{\_\_\_\_\_\_\_\_}{5252}$ x 746

= 27083 WATTS

B. Core Loss + Windage and Friction (@ Rated Voltage)

Watts = $\frac{F\ L\ N}{5252}$ x 746

= ________ x 746

= ________ WATTS

Core Loss B-A

= ______ - ______

= 8502 WATTS

C. Armature Copper Loss (Stray Load Loss Test)

Watts = I^2_{arm} x R x 3

= ($)^2$ ( ) (3)

= ________ WATTS

Where: I = RATED ARMATURE CURRENT
R = ARMATURE RESISTANCE PER PHASE AT TIME OF THE STRAY LOAD LOSS TEST.

D. Stray Load Loss + I^2R Loss + Friction & Windage (@ Rated Armature Current)

Watts = $\frac{F\ L\ N}{5252}$ x 746

= $\frac{\_\_\_\_\_\_\_\_}{5252}$ x 746

= ________ WATTS

I-21

Stray Load Loss = D-(A + C)

$\left(\frac{889}{1504}\right)^2 (3447)$ = 1205 - (____ + ____)

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75 % LOAD @ 1.0 PF

EFFICIENCY CALCULATIONS

KATO ENGINEERING CO.

Mankato, Minnesota

S/N
MODEL
MIL-STD-705
METHOD 415.0
DATE

E. Armature I^2R Loss

Watts = I^2_{arm} X R_{75} X 3

= ( )^2 ( ) (3)

$(11912)\left(\frac{889}{1504}\right)^2$ = 4162 Watts

Where: I_{arm} = RATED ARMATURE CURRENT

R_{75} = RESISTANCE PER PHASE Corrected to 75°c

R_{75} = $\frac{234.5 + 75}{234.5 +}$ X ohms

= $\frac{309.5}{}$ X ohms

= ohms

F. Generator Field I^2 X R Loss

$I_{FLD} = (37.3 - 26)(.75) + 26$

=

WATTS = I^2R

$= (34.4)^2 (1.636)$

= 1936

Where: I_f = FIELD CURRENT AT RATED LOAD

R_{75} = RESISTANCE OF THE FIELD CORRECTED TO 75°c

R_{75} = $\frac{234.5 + 75}{234.5 +}$ X ohms

= $\frac{309.5}{}$ X ohms

= ohms

Total Losses (Watts)

1. Friction & Windage Loss	27083
2. Core Loss	8502
3. Stray Load Loss	1202
4. Armature I^2R Loss	4162
5. Field I^2R Loss	1936
6 EXCITER	263
	43148

Efficiency:

% Eff. = 100 - $\frac{\text{Losses x 100}}{\text{Output + Losses}}$

= 100 - $\frac{(43148)\ (100)}{750{,}000 + 43148}$

= 100 - 5.44

% Eff. = 94.55

1-22

50 % LOAD @ 1.0PF

EFFICIENCY CALCULATIONS

KATO ENGINEERING CO.

Mankato, Minnesota

S/N 74526
MODEL 1000ER9E
MIL-STD 705
METHOD 1150
DATE 30 NOV 1976

A. Friction & Windage Loss (No Excitation)

Watts = $\frac{F\ L\ N}{5252}$ x 746 Where: F = NET FORCE IN LBS.

L = LEVER ARM IN FT.

N = SPEED OF DYNOMOMETER IN RPM

= $\frac{\_\_\_\_\_\_}{5252}$ x 746

= 27083 WATTS

B. Core Loss + Windage and Friction (@ Rated Voltage)

Watts = $\frac{F\ L\ N}{5252}$ x 746

= ______ x 746

= ______ WATTS

Core Loss B-A

= ______ - ______

= 8502 WATTS

C. Armature Copper Loss (Stray Load Loss Test)

Watts = I^2_{arm} x R x 3 Where: I = RATED ARMATURE CURRENT

= ($)^2$ ( ) (3) R = ARMATURE RESISTANCE PER PHASE AT TIME OF THE STRAY LOAD LOSS TEST.

= ______ WATTS

D. Stray Load Loss + I^2R Loss + Friction & Windage (@ Rated Armature Current)

Watts = $\frac{F\ L\ N}{5252}$ x 746

= $\frac{\_\_\_\_\_\_}{5252}$ x 746

= ______ WATTS

Stray Load Loss = D-(A + C)

$\left(\frac{601}{1504}\right)^2$ 3441.7 = 550 - (___ + ___)

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50 % LOAD @ 1.0PF

EFFICIENCY CALCULATIONS

KATO ENGINEERING CO.

Mankato, Minnesota

S/N 74526
MODEL 1000 ER96
MIL-STD-705
METHOD 415.0
DATE 30 NOV 1976

E. Armature I^2R Loss

Watts = $I^2_{arm} \times R_{75} \times 3$

= ( )^2 ( ) (3)

$\left(\frac{601}{1504}\right)^2 (11912)$ = 1902 Watts

Where: I_{arm} = RATED ARMATURE CURRENT

R_{75} = RESISTANCE PER PHASE Corrected to 75°c

R_{75} = $\frac{234.5 + 75}{234.5 +}$ X ohms

= $\frac{309.5}{}$ X ohms

= ohms

F. Generator Field $I^2 \times R$ Loss

$I_{FLD} = (37.3 - 26)(.5) + 26$

$= 31.65$

WATTS = $I^2 R$

$= (31.65)^2 \; 1.636$

$= 1639$

Where: I_f = FIELD CURRENT AT RATED LOAD

R_{75} = RESISTANCE OF THE FIELD CORRECTED TO 75°c

R_{75} = $\frac{234.5 + 75}{234.5 +}$ X ohms

= $\frac{309.5}{}$ X ohms

= ohms

Total Losses (Watts)

1.	Friction & Windage Loss	27083
2.	Core Loss	8502
3.	Stray Load Loss	550
4.	Armature I^2R Loss	1902
5.	Field I^2R Loss	1639
6.	EXCITER LOSSES	222
		39898

Efficiency:

% Eff. = $100 - \frac{\text{Losses} \times 100}{\text{Output} + \text{Losses}}$

$= 100 - \frac{(39898)(100)}{500{,}000 + 39898}$

$= 100 - 7.39$

% Eff. = 92.61

20% LOAD @ 1.0 PF

EFFICIENCY CALCULATIONS

KATO ENGINEERING CO.

Mankato, Minnesota

S/N 74526
MODEL 1000 ER9E
MIL-STD 705
METHOD 415.0
DATE 30 NOV 1976

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A. Friction & Windage Loss (No Excitation)

Watts $= \frac{F\ L\ N}{5252} \times 746$

Where: F = NET FORCE IN LBS.

L = LEVER ARM IN FT.

N = SPEED OF DYNOMOMETER IN RPM

$= \frac{\rule{3cm}{0.4pt}}{5252} \times 746$

= 27083 WATTS

B. Core Loss + Windage and Friction (@ Rated Voltage)

Watts $= \frac{F\ L\ N}{5252} \times 746$

= ______________ x 746

= ______________ WATTS

Core Loss B-A

= ________ - ________

= 8502 WATTS

C. Armature Copper Loss (Stray Load Loss Test)

Watts $= I^2_{arm} \times R \times 3$

Where: I = RATED ARMATURE CURRENT

R = ARMATURE RESISTANCE PER PHASE AT TIME OF THE STRAY LOAD LOSS TEST.

$= (\quad)^2 (\quad) (3)$

= __________ WATTS

D. Stray Load Loss + I^2R Loss + Friction & Windage (@ Rated Armature Current)

Watts $= \frac{F\ L\ N}{5252} \times 746$

$= \frac{\rule{3cm}{0.4pt}}{5252} \times 746$

= ______________ WATTS

Stray Load Loss = D-(A + C)

$\left(\frac{240}{1504}\right)^2 3447$ = 88 - (______ + ______)

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EFFICIENCY CALCULATIONS

KATO ENGINEERING CO.

Mankato, Minnesota

S/N
MODEL
MIL-STD-705
METHOD 415.0
DATE

E. Armature I^2R Loss

Watts = I^2_{arm} X R_{75} X 3

$\left(\frac{240}{1504}\right)^2 (11912) = (\quad)^2 (\quad)(3)$

= 303 Watts

Where: I_{arm} = RATED ARMATURE CURRENT

R_{75} = RESISTANCE PER PHASE Corrected to 75°c

R_{75} = $\frac{234.5 + 75}{234.5 + 25}$ X ohms

= $\frac{309.5}{\quad}$ X ohms

= ohms

F. Generator Field I^2 X R Loss

$I_{FLD} = (37.3 - 26)(.2) + 26$
$= 28.26$

WATTS = I^2R
$= (28.26)^2 (1.636)$
$= 1306$

Where: I_f = FIELD CURRENT AT RATED LOAD

R_{75} = RESISTANCE OF THE FIELD CORRECTED TO 75°c

R_{75} = $\frac{234.5 + 75}{234.5 +}$ X ohms

= $\frac{309.5}{\quad}$ X ohms

= ohms

Total Losses (Watts)

1. Friction & Windage Loss 27083
2. Core Loss 8502
3. Stray Load Loss 88
4. Armature I^2R Loss 303
5. Field I^2R Loss 1306
6. EXCITER LOSSES 177

Efficiency: 37459

% Eff. = 100 - $\frac{\text{Losses x 100}}{\text{Output + Losses}}$

= 100 - $\frac{(37459)(100)}{200{,}000 + 37459}$

= 100 - 15.77

% Eff. = 84.22

10 % LOAD @ 1.0 PF

EFFICIENCY CALCULATIONS

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KATO ENGINEERING CO.

Mankato, Minnesota

S/N 74526
MODEL 1000E296
MIL-STD 705
METHOD 415.0
DATE 30 NOV 1976

A. Friction & Windage Loss (No Excitation)

Watts = $\frac{F\ L\ N}{5252}$ x 746

= $\frac{\qquad}{5252}$ x 746

= 27083 WATTS

Where: F = NET FORCE IN LBS.

L = LEVER ARM IN FT.

N = SPEED OF DYNOMOMETER IN RPM

B. Core Loss + Windage and Friction (@ Rated Voltage)

Watts = $\frac{F\ L\ N}{5252}$ x 746

= ________ x 746

= ________ WATTS

Core Loss B-A

= ______ - ______

= 8502 WATTS

C. Armature Copper Loss (Stray Load Loss Test)

Watts = I^2_{arm} x R x 3

= ($)^2$ ( ) (3)

= ________ WATTS

Where I = RATED ARMATURE CURRENT

R = ARMATURE RESISTANCE PER PHASE AT TIME OF THE STRAY LOAD LOSS TEST.

D. Stray Load Loss + I^2R Loss + Friction & Windage (@ Rated Armature Current)

Watts = $\frac{F\ L\ N}{5252}$ x 746

= $\frac{\qquad}{5252}$ x 746

= ________ WATTS

Stray Load Loss = D-(A + C)

$\left(\frac{120}{1504}\right)^2$ 3447 = 22 - (— + ____)

10 % LOAD @ 1.0 PF

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EFFICIENCY CALCULATIONS

KATO ENGINEERING CO.

Mankato, Minnesota

S/N 74526
MODEL 1000 ER9E
MIL-STD-705
METHOD 415.0
DATE 30 NOV 1977

E. Armature I^2R Loss

Watts = $I^2_{arm} \times R_{75} \times 3$

= ( )^2 ( ) (3)

$\left(\frac{120}{1504}\right)^2 (11912)$ = 76.0 Watts

Where: I_{arm} = RATED ARMATURE CURRENT

R_{75} = RESISTANCE PER PHASE Corrected to 75°c

R_{75} = $\frac{234.5 + 75}{234.5 + 25}$ X ohms

= $\frac{309.5}{}$ X ohms

= ohms

F. Generator Field $I^2 \times R$ Loss

$I_{FLD} = (37.3 - 26)(.1) + 26$

$= 27.13$

WATTS $= I^2R$

$= (27.13)^2 (1.636)$

$= 1204$ WATTS

Where: I_f = FIELD CURRENT AT RATED LOAD

R_{75} = RESISTANCE OF THE FIELD CORRECTED TO 75°c

R_{75} = $\frac{234.5 + 75}{234.5 +}$ X ohms

= $\frac{309.5}{}$ X ohms

= ohms

Total Losses (Watts)

1. Friction & Windage Loss	27083
2. Core Loss	8502
3. Stray Load Loss	22
4. Armature I^2R Loss	76
5. Field I^2R Loss	1204
6 Exciter Losses	163
	37050

Efficiency:

% Eff. = 100 - $\frac{\text{Losses} \times 100}{\text{Output} + \text{Losses}}$

= 100 - $\frac{(37050)(100)}{100{,}000 + 37050}$

= 100 - 27.03

% Eff. = 72.96

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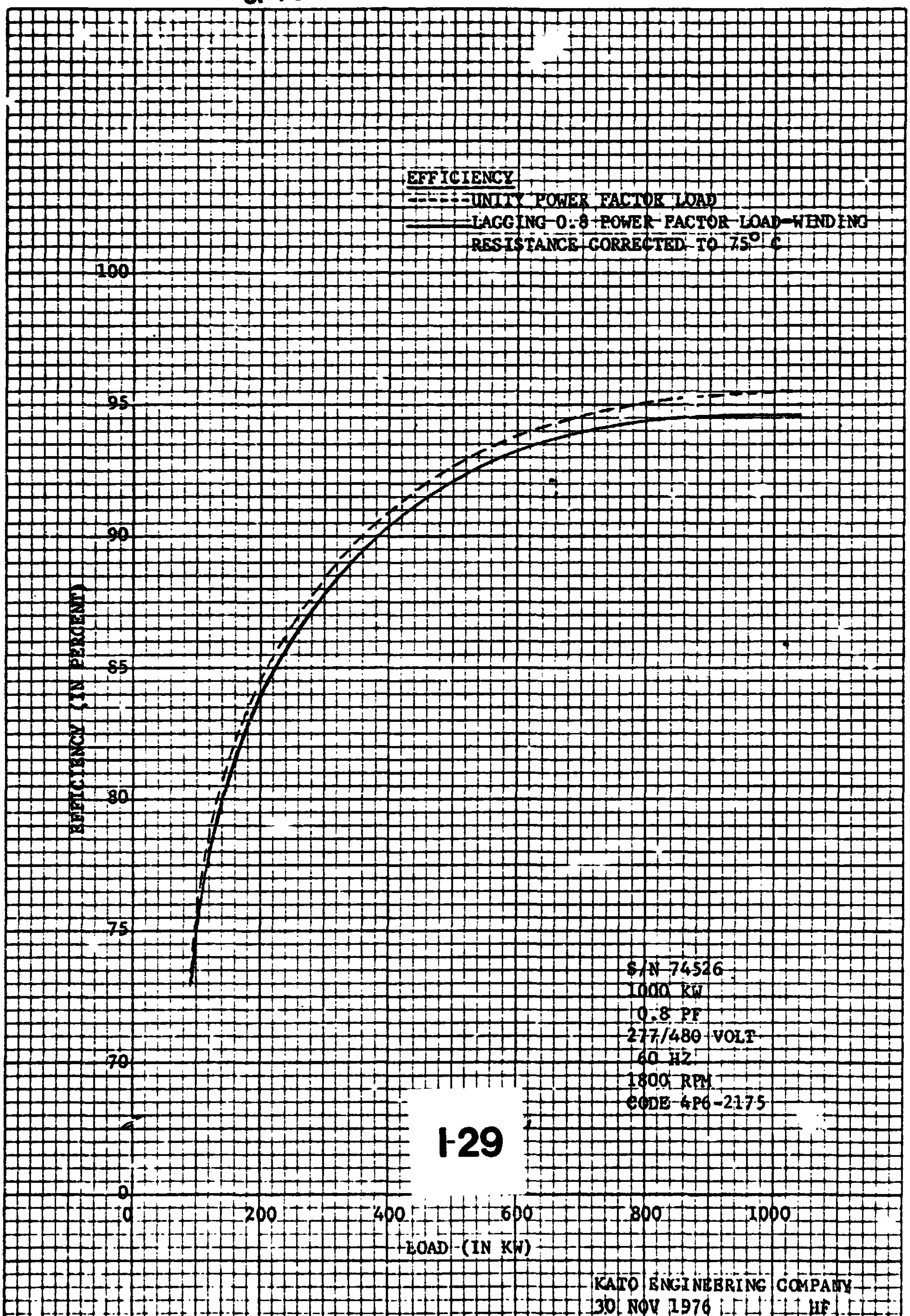
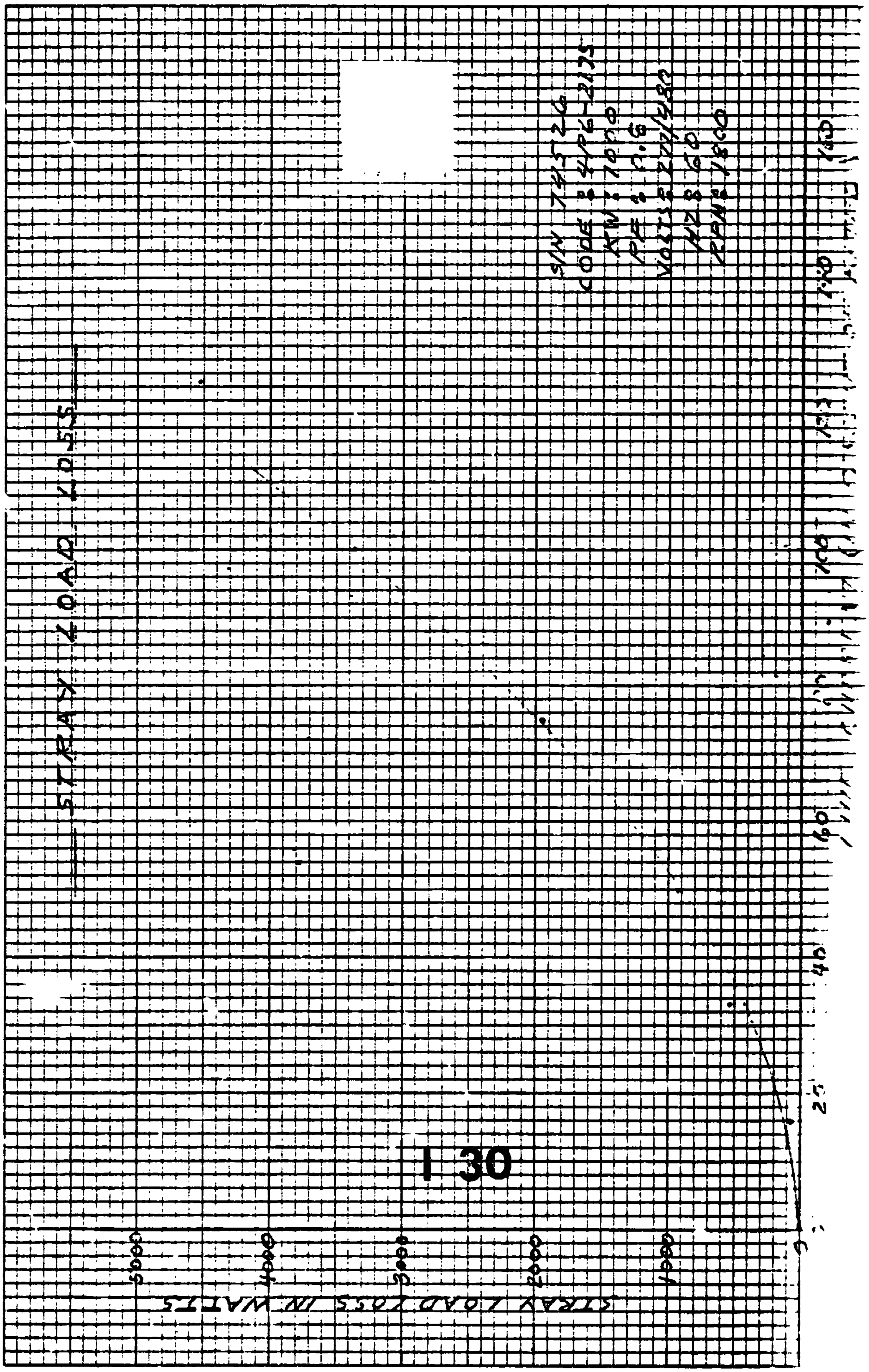


I-29

NO. 340-10 DIETZGEN GRAPH PAPER
10 X 10 PER INCH
DIETZGEN CORPORATION
MADE IN U.S.A.


STRAY LOAD LOSS
KW: 1000
HZ: 60
RPM: 1800
STRAY LOAD LOSS IN WATTS
1000
2000
3000
4000
5000
25
40
60
80
100
120
140
160

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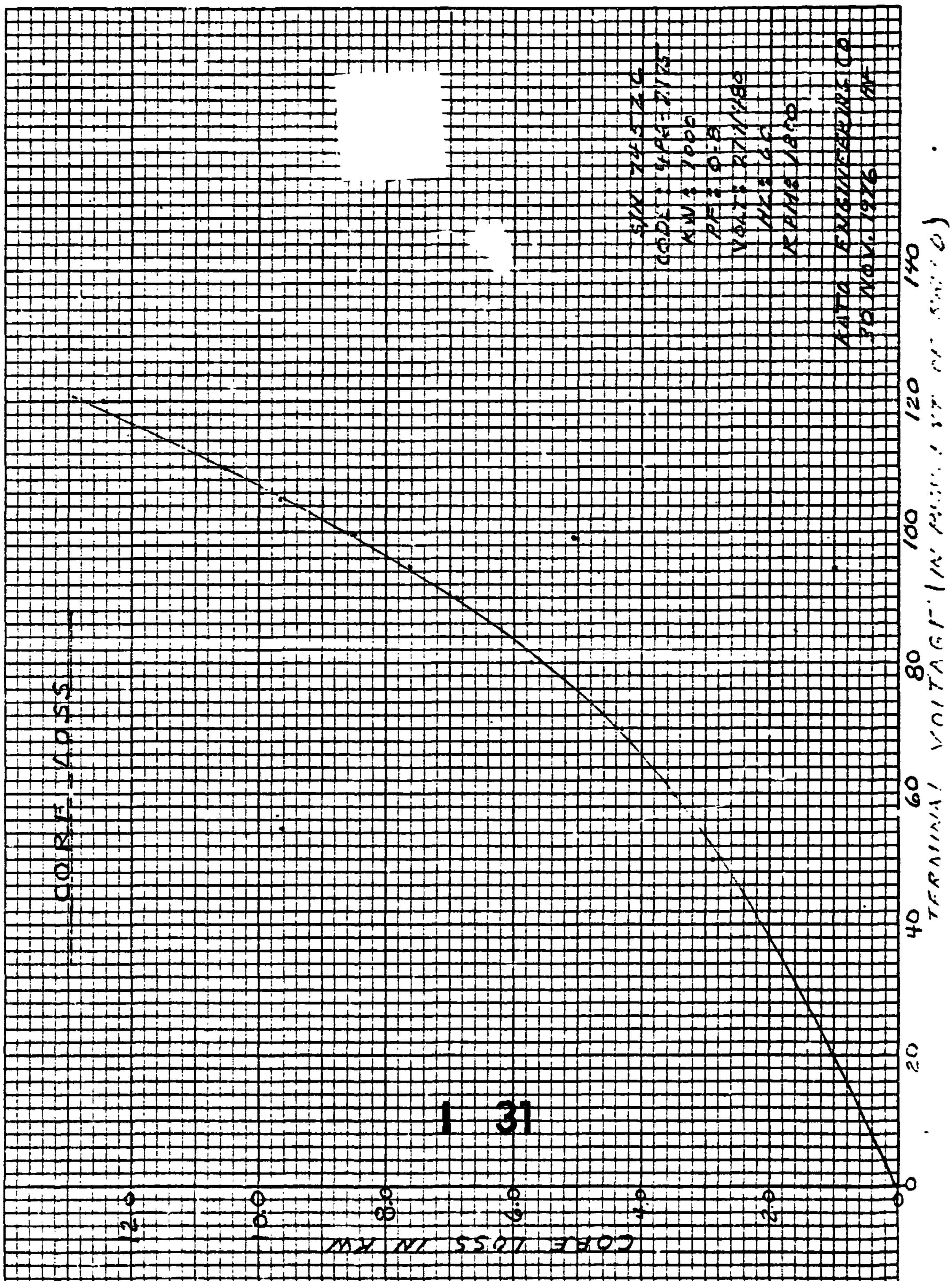

I 31

KATO ENGINEERING CO. MANKATO, MINNESOTA

ORDER SERIAL NO. 74526 DATE______ SOLD TO______

MODEL______ TYPE NO.______ UNIT NO.______ TESTED BY:______

KVA______ KW______ A.C. VOLTS______ CYCLES______ RPM______

D.C. VOLTS______ TEMP RISE______ ROTATION, FACING DRIVE END______

WAVE FORM HARMONICS (PER CENT OF FUNDAMENTAL. FUNDAMENTAL 100%)

HARMONIC NUMBER	NO LOAD		1/4 LOAD		2/4 LOAD		3/4 LOAD		4/4 LOAD		5/4 LOAD	
	L-L	L-N	L-L	L-N	L-L	L-N	L-L	L-N	L-L	L-N	L-L	L-N
1	100.0								100.0			
3	0.090	0.070							0.070	0.080		
5	1.090	1.110							0.810	0.870		
7	0.860	0.870							0.770	0.990		
9	0.000	0.010							0.010	0.000		
11	0.100	0.100							0.360	0.350		
13	0.230	0.230							0.390	0.390		
15	0.000	0.000							0.000	0.000		
17	0.050	0.050							0.090	0.090		
19	0.060	0.060							0.080	0.090		
21	0.000	0.000							0.010	0.000		
23	0.000	0.010							0.020	0.030		
25	0.020	0.020							0.010	0.000		
27	0.000	0.000							0.000	0.000		
29	0.090	0.100							0.110	0.110		
31	0.240	0.240							0.250	0.250		
33	0.000	0.010							0.010	0.010		
35	0.010	0.010							0.020	0.020		
37	0.010	0.010							0.010	0.010		
39	0.000	0.000							0.000	0.000		
MODULATION	NONE	TO BE	SEEN									
TOTAL DISTORTION	1.30	1.25							1.31	1.28		
DEVIATION FACTOR	2.60	2.55							2.40	2.40		

TEST RECORD

KATO ENGINEERING CO.

MANKATO, MINNESOTA U.S.A.

SERIAL NO. 24526-1
MODEL 10 2 ER9E
TYPE NO. 1356
PHASE 3 Ø
KVA 1250 KW 1000
VOLTS 480
FREQ. 60 RPM 1800
TEMP. RISE
ROTATION CWFDE
EXCITATION

CUSTOMER SWEINHART ELEC
P.O. OR CONTRACT NO.
4513- R2686A

TEST LOAD FOR
1/4 LOAD CHANGE
STRIP CHART

DATE 11-30-76
SPEC.
METHOD
TESTED BY LmHewitt
PD Krabauer
GOV'T. INSP.

INST. / READ NO.	TIME										AVG. AMB. TEMP.
UNITS / FACTOR		ACV	ACI	KVA	KW	PF	HZ	EFV	EFI		
		480	376	312.5	109	.33	59.7	18.8	1.65		
		480	0				59.8	13.8	1.20		

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REMARKS

SHEET OF

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TEST RECORD

KATO ENGINEERING CO.

MANKATO, MINNESOTA U.S.A.

SERIAL NO. 74536-1
MODEL 1000ER9E
TYPE NO. 18R56
PHASE 3Ø
KVA 1250 KW 1000
VOLTS 480
FREQ. 60 RPM 1800
TEMP. RISE
ROTATION CWFDE
EXCITATION

CUSTOMER SWEINHART ELEC.
P.O. OR CONTRACT NO. 14513-R2686A

TEST OVERSPEED

DATE 11/30/76
SPEC.
METHOD
TESTED BY J. M. HEWITT / P D KRALOWETZ
GOV'T. INSP.

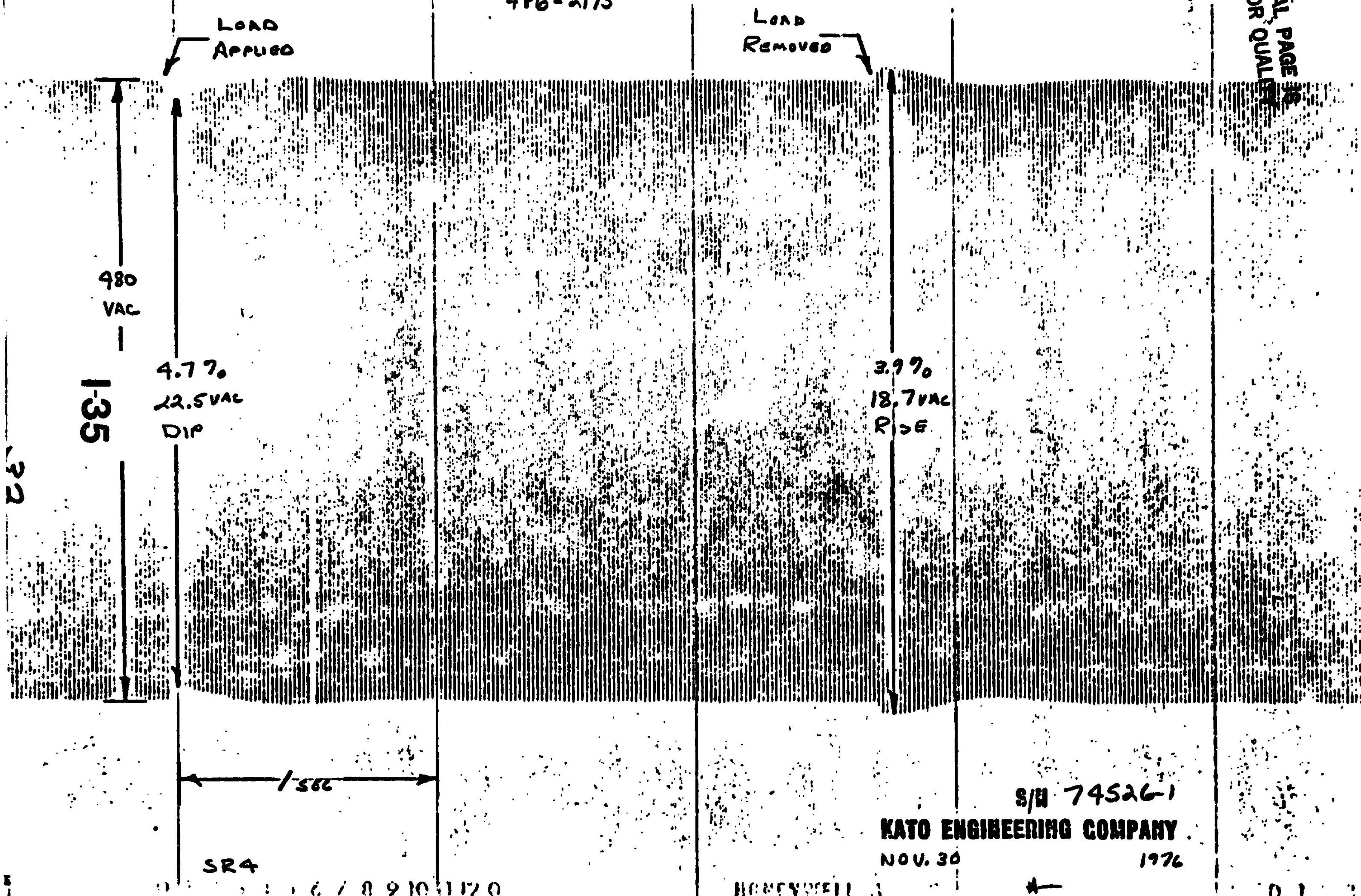
INST.						
READ NO.	TIME					AVG. AMB. TEMP.
UNITS						
FACTOR		TIME MINUTES	RPM	HZ	% OF OVER SPEED	
		0	2238	74.6	124.3	
		1	2238	74.6	124.3	
		2	2238	74.6	124.3	
		3	2238	74.6	124.3	
		4	2238	74.6	124.3	
		5	2238	74.6	124.3	

REMARKS: Everything looked great. No problems

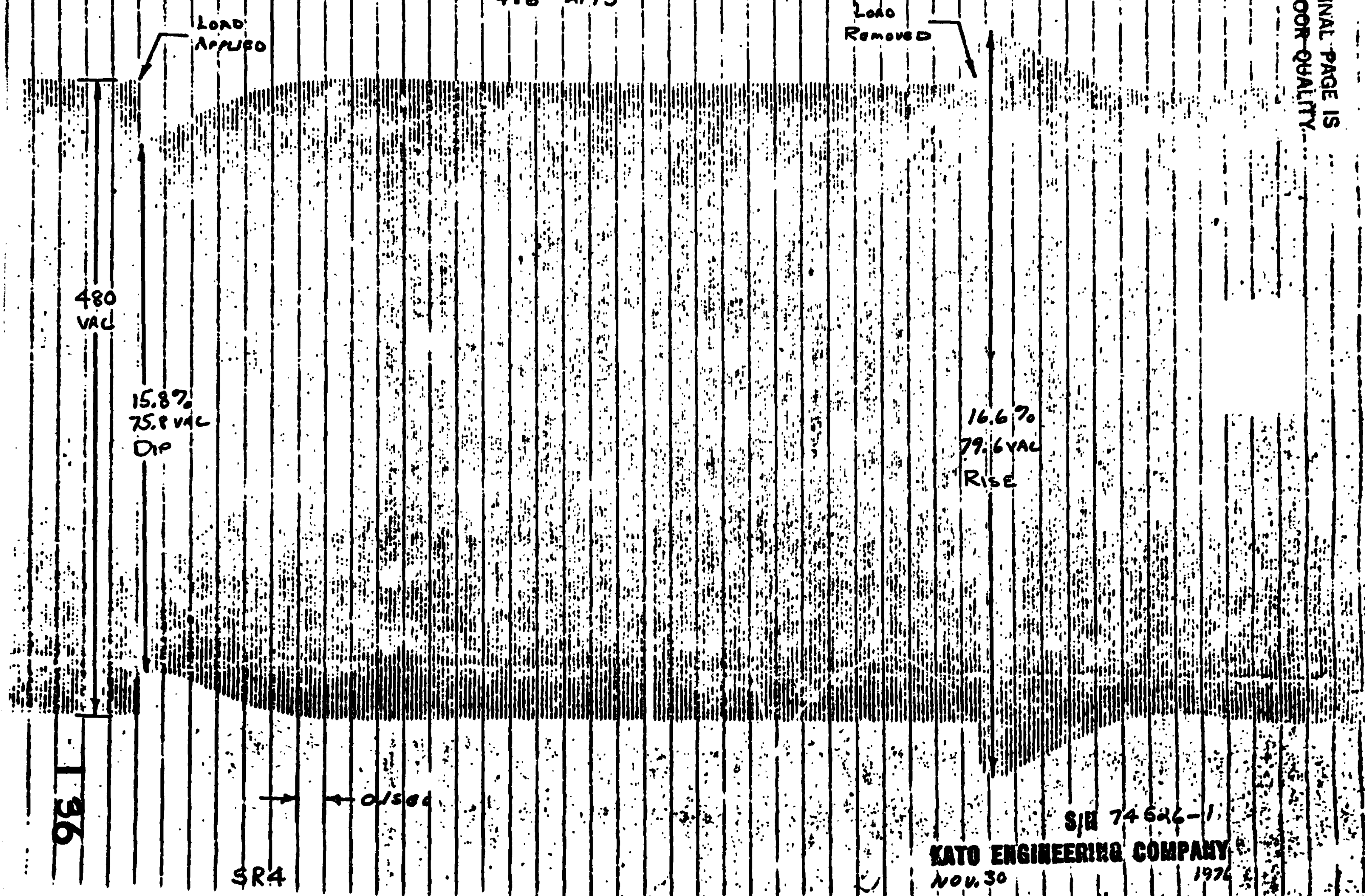
SHEET ___ OF ___

1-34

VOLTAGE TRANSIENTS & RESPONSE TIME
NO LOAD (312.5KVA @ .33 P. F.) 25 % LOAD
4P6-2175



VOLTAGE TRANSIENTS & RESPONSE TIME
(NO LOAD (1000 KW @ 0.0 P. F.) FULL LOAD
4P6-2175



S/N 74526-1
KATO ENGINEERING COMPANY
NOV. 30 1976

KATO ENGINEERING CO.
MANKATO, MINNESOTA

ORDER SERIAL NO. 74526 DATE 11/23/76 SOLD TO: Sweihart Electric Co Inc

MODEL 1000ER9E TYPE NO. 18856 UNIT NO. 1 TESTED BY: LmHewitt
PD Kralovec

UNIT SPECIFICATIONS

KVA 1250 KW 1000 A.C. VOLTS 480 CYCLES 60 RPM 1800

C. VOLTS ______ TEMP. RISE 70°C ROTATION, FACING DRIVE END CW

OPEN CIR SAT

%	ACV	ACI	KVA	KW	PF	HZ	EFV	EFI	GFV	GFI
151	726	0					90.0	7.60	182	126.3
150	720	0					77.6	6.45	166	118.9
140	672	0					44.3	3.68	112.2	77.9
130	624	0					30.0	2.510	78.5	64.5
120	576	0					22.0	1.850	58.8	41.9
110	528	0					16.6	1.430	45.7	33.2
105	504	0					14.9	1.270	40.3	29.4
100	480	0					13.3	1.160	37.1	27.2
95	456	0					12.2	1.070	34.0	25.5
80	384	0					8.9	.770	25.9	19.7
70	336	0					6.8	.680	22.1	16.8
60	288	0					6.0	.530	18.2	14.9
50	240	0					4.9	.492	15.0	12.3
40.	192	0					3.3	.316	11.9	10.2
Res.	39.0	0					0	OPEN	2.0	3.3
145	696	0					58.7	5.000	141.2	88.9
143.5	689	0					53.5	4.50	132.1	91.7
141.9	679	0					47.3	4.00	120.2	83.9
138.8	666	0					41.8	3.50	107.8	74.7
134.6	646	0					35.7	3.00	93.2	65.4
122.5	588	0					23.8	2.00	64.6	46.8
100	480	0					13.7	1.17	37.3	29.9

KATO ENGINEERING CO.
MANKATO, MINNESOTA

ORDER SERIAL NO. 74526 DATE 11/23/76 SOLD TO: SweiHart Electric Co Inc

MODEL 1000ER9E TYPE NO. 18856 UNIT NO. 1 TESTED BY: LM Hewitt PDKralovec

UNIT SPECIFICATIONS

KVA 1250 KW 1000 A.C. VOLTS 480 CYCLES 60 RPM 1800

D.C. VOLTS ______ TEMP. RISE 70°C ROTATION, FACING DRIVE END CW

SHORT CIR SAT

%	ACV	ACI	RPM	EFV	EFI	GFV	GFI
150	0.0	2256	1800	25.9	2.23	66.5	50.3
125	0.0	1880	1800	21.9	1.84	54.8	42.0
100	0.0	1504	1800	16.9	1.36	43.7	34.6
75	0.0	1128	1800	12.1	1.05	32.8	26.9
50	0.0	752	1800	7.2	.66	21.9	19.2
25	0.0	376	1800	3.1	.276	10.6	11.6

.25

KATO ENGINEERING CO.
MANKATO, MINNESOTA

ORDER SERIAL NO. 74526 DATE 11/23/76 SOLD TO: SweitHart Electric Co Inc

MODEL 1000ER9E TYPE NO. 18856 UNIT NO. 1 TESTED BY: LmHewitt PDKralovec

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UNIT SPECIFICATIONS

KVA 1250 KW 1000 A.C. VOLTS 480 CYCLES 60 RPM 1800

. VOLTS ____ TEMP. RISE 70°C ROTATION, FACING DRIVE END CW

ZERO-POWER SAT.

I-39

%	ACV	ACI	KVA	KW	PF	HZ	EFV	EFI	GFV	GFI
130	624	1504	1625	—	0.0	59.69	78.2	6.62	170	130.9
120	576	1504	1500	—	0.0	59.91	55.9	4.64	136.4	96.0
110	528	1504	1375	—	0.0	59.93	49.1	3.66	113.1	79.9
105	504	1504	1312.5	—	0.0	59.93	40.3	3.34	1050	73.7
100	480	1504	1250	—	0.0	59.93	37.3	3.10	97.9	69
95	456	1509	1187.5	—	0.0	59.93	35.4	2.94	92.5	64.8
80	384	1509	1000	—	0.0	59.93	30.6	2.57	80.9	57.2
70	336	1509	875	—	0.0	59.93	28.2	2.35	74.7	53.4
60	288	1504	750	—	0.0	59.93	26.2	2.19	69.4	49.5
50	240	1509	625	—	0.0	59.93	24.3	2.04	65.1	46.7
40	192	1504	500	—	0.0	59.99	22.5	1.89	60.9	44.1

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KATO ENGINEERING CO.
MANKATO, MINNESOTA

ORDER SERIAL NO. 74536 DATE 11/23/76 SOLD TO: Sweihart Electric Co Inc

MODEL 1000ER9E TYPE NO. 18856 UNIT NO. 1 TESTED BY: bm Hewitt
PD Kralovec

UNIT SPECIFICATIONS

KVA 1250 KW 1000 A.C. VOLTS 480 CYCLES 60 RPM 1800

D.C. VOLTS ______ TEMP. RISE 70 °C ROTATION, FACING DRIVE END CW

Load Test

AV	ACI	KVA	KW	PF	Hz	EFV	EFI	GFV	GFI
480	1504	1260	–	0.0	59.93	37.6	3.17	97.5	68.9
650	0				59.92	37.6	3.17	97.5	68.9
480	301	250	250	1.0	59.62	49.9	1.27	39.6	30.9
492	0				60.0	49.9	1.27	39.6	30.9
480	376	312.5	250	0.8	59.62	17.8	1.54	47.1	36.0
533	0				60.0	17.6	1.54	47.2	36.0

I-40

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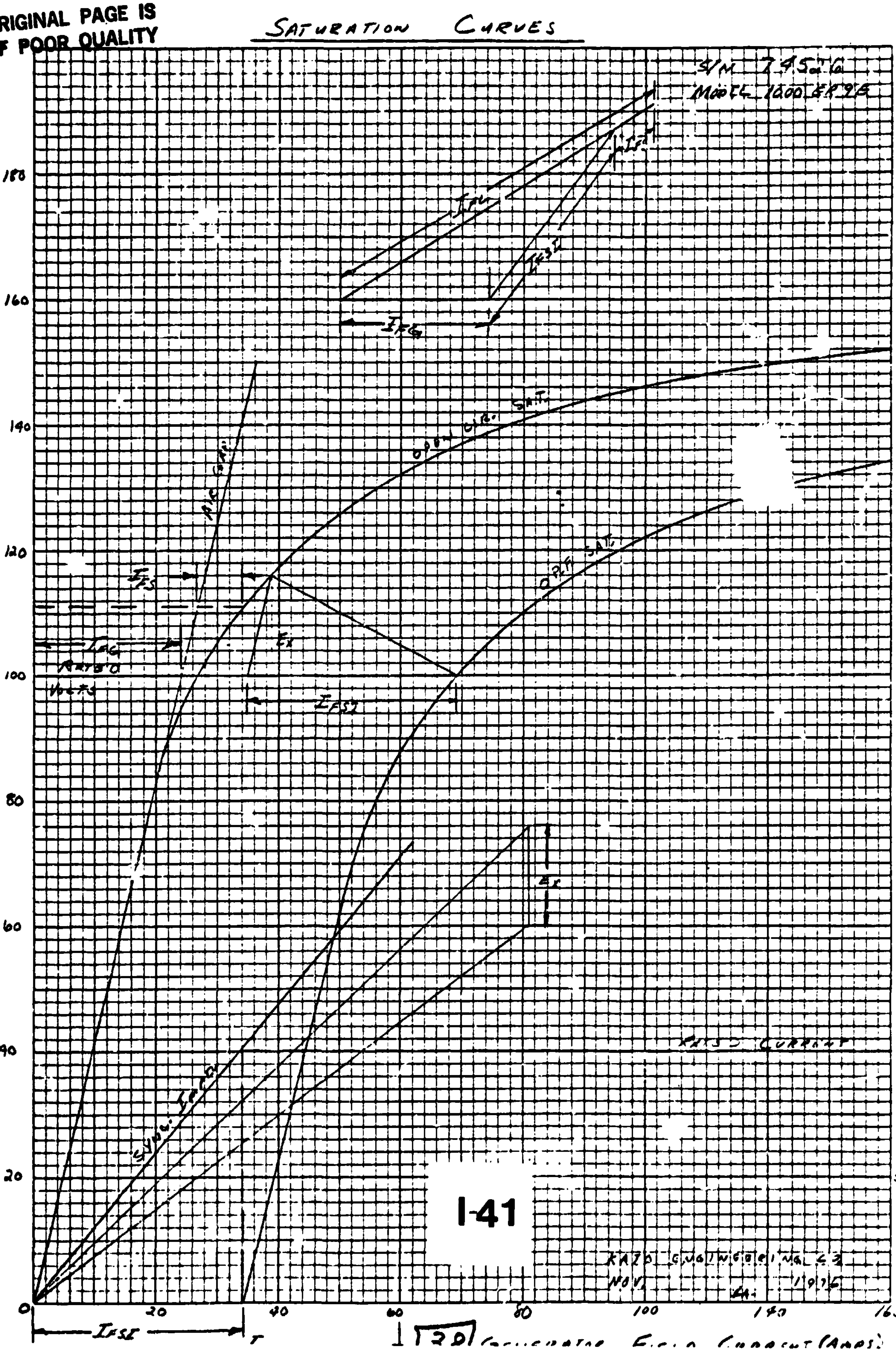

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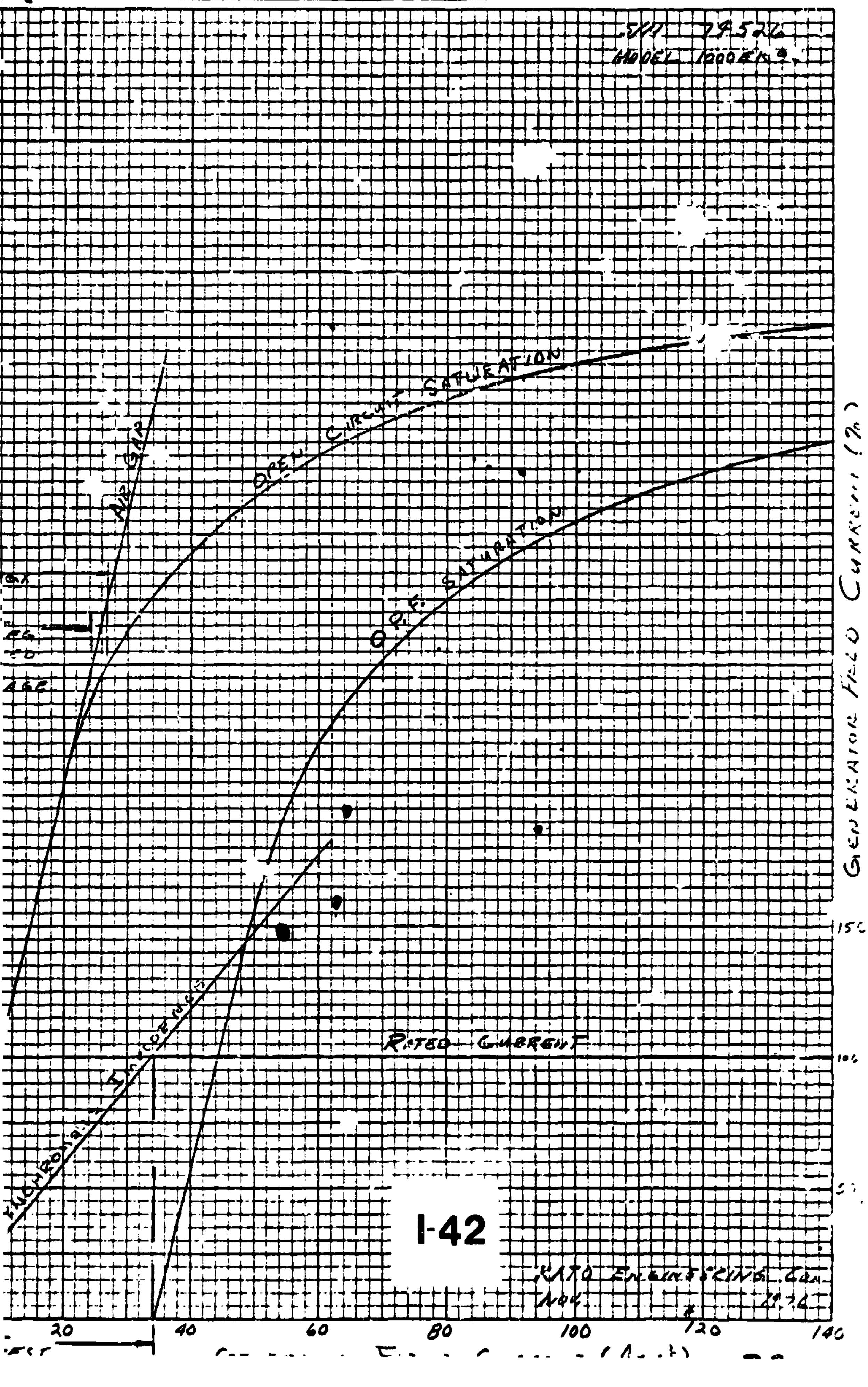
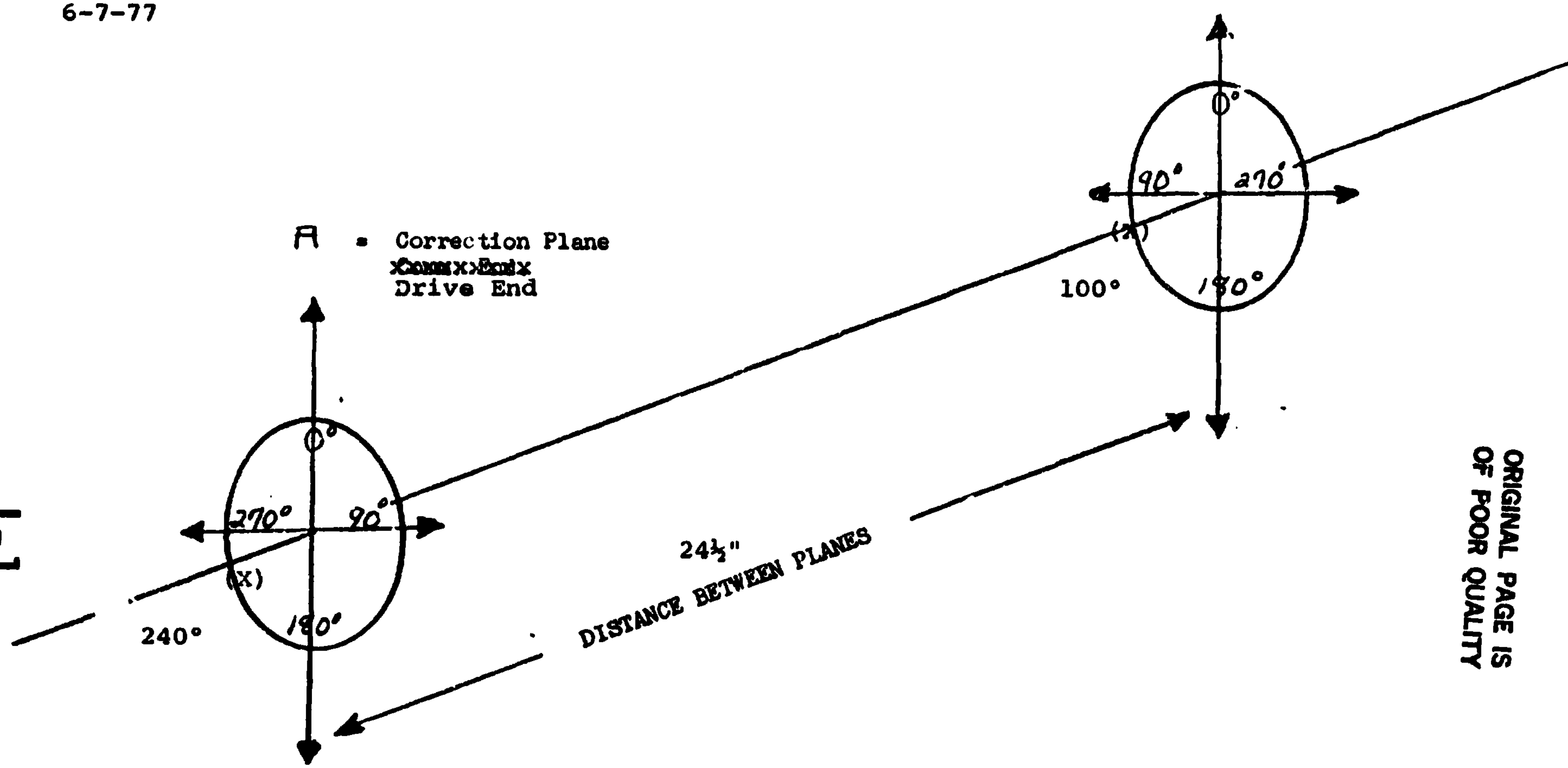


I-42

Small Impeller
6-7-77



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J-1

CUSTOMER Hydrothermal Power

ORIGINAL VIB. AMP.	128 Gr. In.
FINAL VIB. AMP.	5 Gr. In.
WEIGHT ~~ADDED~~/REMOVED	16 Grams
RADIUS	7½"
PERMANENT CORRECTION MADE BY ~~ADDITION~~/REMOVAL OF WEIGHT	

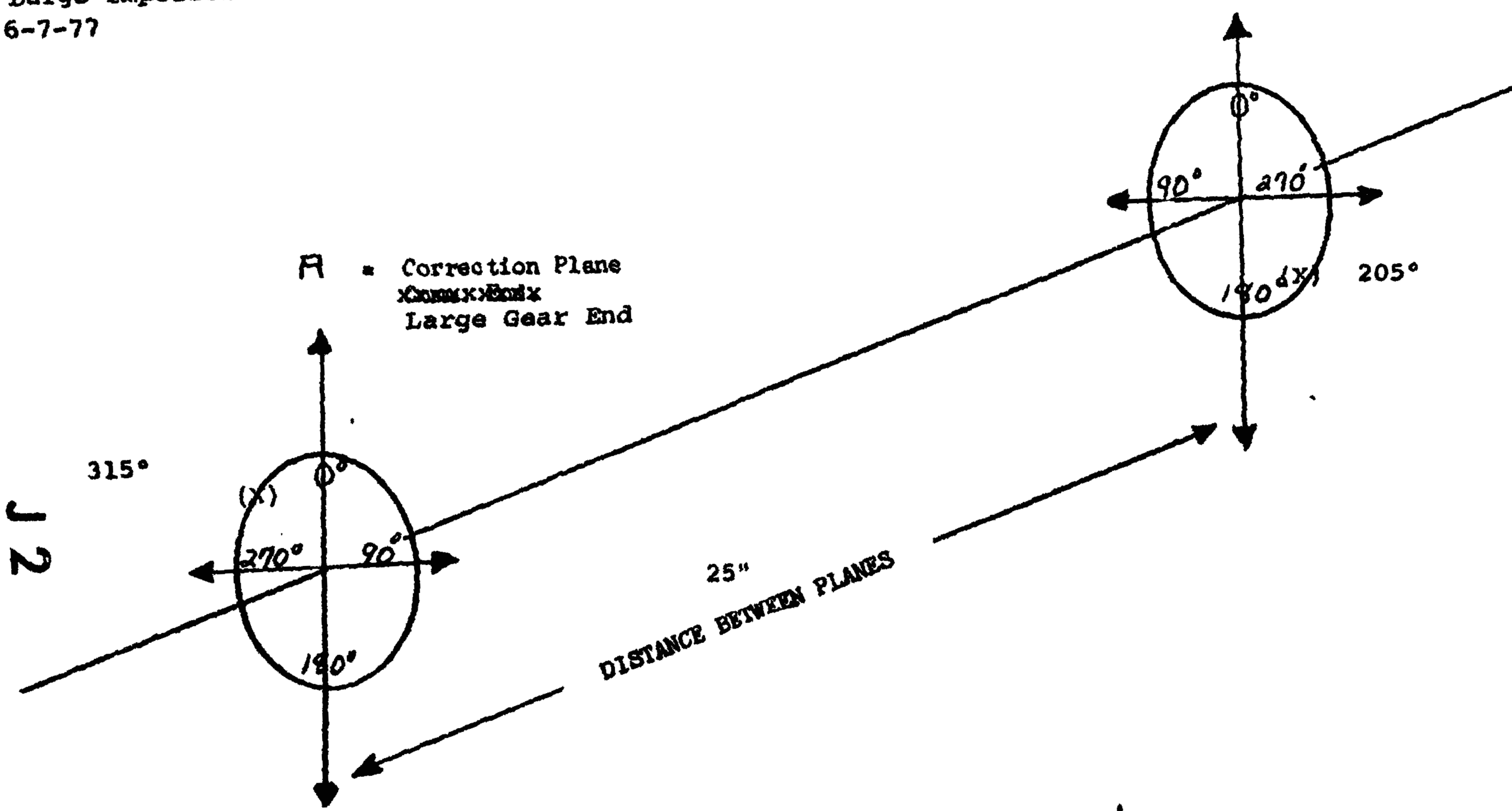
P.O.#	W.O.#	DEL.#	APPROX. WT.
	5691	6721	1500 lbs.

ELECTRONIC BALANCING CO.
2849 Long Beach Blvd.
Long Beach, Calif. 90806
GArfield 4-0739 NEvada 6-6538

ORIGINAL VIB. AMP.	120 Gr. In.
FINAL VIB. AMP.	5 Gr. In.
WEIGHT ~~ADDED~~/REMOVED	15 Grams
RADIUS	7½"
PERMANENT CORRECTION MADE BY ~~ADDITION~~/REMOVAL OF WEIGHT	

Large Impeller
6-7-77

J 2



ORIGINAL VIB. AMP.	97.5 Gr. In.
FINAL VIB. AMP.	5 Gr. In.
WEIGHT ~~ADDED~~/REMOVED	13 Grams
RADIUS	7½"
PERMANENT CORRECTION MADE BY ~~ADDITION~~/REMOVAL OF WEIGHT	

CUSTOMER Hydrothermal Power

P.O.#	W.O.#	DEL.#	APPROX. WT.
	5691	6721	1750 lbs

ELECTRONIC BALANCING CO.
2849 Long Beach Blvd.
Long Beach, Calif. 90806
GArfield 4-0739 NEvada 6-6538

ORIGINAL VIB. AMP.	150 Gr. In.
FINAL VIB. AMP.	5 Gr. In.
WEIGHT ~~ADDED~~/REMOVED	20 Grams
RADIUS	7½"
PERMANENT CORRECTION MADE BY ~~ADDITION~~/REMOVAL OF WEIGHT	

R.A. McKay
Final Draft

ACCEPTANCE AND INTERFACE TESTING

A. PURPOSES

1. To verify that the HPC Power System 76-1 (a) complies with the contract specifications as embodied in Contract 954404, Exhibit 1, and HPC Drawings B13 and B14, (b) is a complete and functioning subsystem in compliance with HPC Drawing B20, and (c) is ready for delivery to JPL.
2. To verify that the interfaces between the HPC Power System 76-1 and the JPL support system are correct and to demonstrate that the Power System and the JPL Control and Instrument Support Van function together as a system.

B. APPROACH

1. HPC assemble, prepare, and check the Power System in Mission Viejo. The preparation should include:
   a. Preset vibration switches (V_1, V_2) to NC (normally closed) plus margin at rest. V_1 ______ V_2 ______
   b. Preset underspeed switch (US) to NO (normally open) at $\sim \lesssim 50$ Hz. ______
   c. Preset high oil temperature (OHT) switch to NC $\lesssim 150$°F. ______
   d. Preset low oil pressure (LOP) switch to NO $\lesssim 10$-12 psig. ______
   e. Preset shaft seal pressure (SSP) switch to NO $\lesssim 125$ psig. ______
   f. Preset overspeed (OS) switch to NC $\lesssim 2200$ RPM = 66 Hz. ______
   g. Preset Stop (S) rate for Automatic Stop valve. ______
   h. Preset Stop (S) rate for Governor Override. ______
   i. Preset Emergency Stop (ES) rate for Automatic Stop valve. ______
   j. Preset Emergency Stop (ES) rate for Governor Override. ______
2. JPL assemble and check the Control and Instrument Support Van equipment and associated cables in Pasadena.

3. When both assemblies are ready, transport Van to Mission Viejo. Park along curb toward front of 25721 Obrero and order air compressors for driving Power System. Compressors will arrive in seven days. When they arrive they will park along Obrero toward rear of 25721.

4. During wait for compressors, JPL will interface with the Power Systems at the terminal strips TB"EA", TB"EB", and TB"EC" in the junction boxes as shown on HPC Drawing B20 . As part of the procedure of interfacing at the terminal strips, each function possible will be checked for end-to-end signal to verify that the JPL and HPC wiring diagrams are correct and correctly executed and that the nomenclature is mutually compatible. Static testing will then be carried out as described under Static Test Procedure, Section C, and the Power System will be checked against Exhibit 1 and HPC Drawings B13 and B14.

5. After the compressors arrive, the Dynamic Acceptance and Interface Testing will be performed as described under Dynamic Test Procedures, Sections D and E.

6. The Load Bank Interface Testing will not be included in Mission Viejo because of insufficient power. Also science data instrumentation testing for brine parameters, pressure, temperature, and flow rate will be postponed to the field, except that at least two unmounted temperature and pressure measuring devices will be wired and monitored.

C. STATIC TEST PROCEDURE

1. Check Batteries. _____

2. Jumper LOP switch. _____ Keep jumpered through step C-22.

3. Reset Emergency Stop relay to energize the safety shutdown circuit. _____

4. Verify that the Exciter switch is in Underspeed Bypass position. _____

5. Activate Data Logger and Intercoms. _____ _____ _____ Log SSP fault. _____

6. Operate pump #1 to prime lube oil system. _____

7. Operate pump #2. _____ At 125 psig monitor no fault. _____ Pressurize to 150 psig. _____ Verify that bearing and winding temperatures, bearing thrust, and throttle position are being logged. See check-list in Appendix.

8. Momentarily turn (key) Start switch. _____ Throttle should open. Observe. _____ Log. _____ Stop relay should reset. _____

9. Operate pump #3 to open Automatic Stop valve fully. _____

10. Press Stop button at power plant. _____ Observe Throttle[b] and Automatic Stop valve close slowly. _____ _____ Estimate closing time of Automatic Stop valve. _____ Log Throttle[b] position. _____

11. Momentarily turn Start switch. _____ Throttle[b] should open. Observe. _____ Log. _____ Stop relay should reset. _____

---

b - Throttle response must be verified. It may be necessary to monitor the Governor Override Stop relay isntead.

_____ _____ _____ _____

Date: Test Staff:

Notes:

12. Press Stop button in Van. _____ Observe Throttle[b] close and Stop relay trip. _____ _____ Estimate closing time of Throttle. _____ Log Throttle[b] position. _____

13. Momentarily turn Start switch. _____ Throttle[b] should open and Stop relay should reset. _____ _____ Log Throttle[b] position. _____

14. Operate pump #3 to open Automatic Stop valve fully. _____

15. Press Emergency Stop button at power plant. _____ Observe Throttle[b] and Automatic Stop valve close rapidly. _____ _____ Estimate closing time of Automatic Stop valve. _____ Log Throttle[b] position. _____

16. Reset Emergency Stop relay. _____ Observe Throttle[b] open and Emergency Stop realy reset. _____ _____ Log Throttle[b] position. _____

17. Press Emergency Stop button in Van. _____ Observe Throttle[b] close and Emergency Stop relay trip. _____ _____ Estimate closing time of Throttle[b]. _____ Log Throttle[b] position. _____

18. Reset Emergency Stop relay. _____ Observe Throttle[b] open and Emergency Stop relay reset. _____ _____ Log Throttle[b] position. _____

19. Underset or otherwise trip vibration switch V_1. _____ Observe Throttle[b] close and Stop relay trip. _____ _____ Log V_1 fault and Throttle[b] position. _____ _____ Reset V_1. _____ Log no fault. _____ Turn Start switch mentarily. _____ Throttle[b] should open and Stop relay should reset. _____ _____ Log Throttle[b] position. _____

---

b - Throttle response must be verified. It may be necessary to monitor the Governor Override Stop instead.

_____ _____ _____ _____

Date: Test Staff:

Notes:

20. Underset or otherwise trip Vibration switch V_2. _____ Observe Throttle[b] close and Stop relay trip. _____ _____ Log V_2 fault and Throttle[b] position. _____ _____ Reset V_2. Log no fault. _____ Turn Start switch. Observe Throttle[b] open and Stop relay reset. _____ _____ Log Throttle[b] position. _____

21. Open OHT circuit. _____ Observe Throttle[b] close and Stop relay trip. _____ _____ Log OHT fault and Throttle[b] position. _____ _____ Restore OHT circuit. _____ Turn Start switch. _____ Observe Throttle[b] open and Stop relay reset. _____ _____

22. Turn Exciter switch to On position to open US bypass. _____ Observe Throttle[b] close and Stop relay trip. _____ _____ Log US fault and Throttle[b] position. _____ _____ Turn Exciter switch to US bypass. _____ Log no fault. _____ Turn Start switch. _____ Observe Throttle[b] open and Start relay reset. _____ _____ Log Throttle[b] position. _____

23. Remove jumper from LOP switch. _____ Observe Throttle[b] close and Stop relay trip. _____ _____ Log LOP fault and Throttle[b] position. _____ _____

24. Open battery circuit by pressing Emergency Stop button. _____ Log all bearing and winding temperature data. _____ Refer to check-list in Appendix.

25. Turn off Data Logger. _____ Turn off Intercoms. _____ _____

---

b - Throttle response must be verified. It may be necessary to monitor the Governor Override Stop instead.

_____ _____ _____ _____

Date: Test Staff:

Notes:

D. DYNAMIC TEST PROCEDURE: MODIFIED START, RUN, STOP

1[c]. Deactivate Governor Override relay for Stop circuit. _____ Install circuitry with auxiliary switches to permit bypassing the OS switch and place a meter across the OS switch terminals. _____ Leave bypass circuit in safety position. _____

2. Inspect the Power Plant, Van, and Cables for readiness. _____ _____ Verify that Main Circuit Breaker is open. _____

3. Check Batteries. _____

4. Reset Emergency Stop relay to energize the safety shutdown circuit. _____

5. Verify that Exciter switch is in Underspeed Bypass position. _____

6. Verify that Automatic Stop and Manual 8" gate valves are closed. _____

7. Turn on compressors. _____ (Wear ear protection as necessary.)

8. Open Manual gate valve fully. _____

9. Operate pump #1 to prime lube oil system. _____

10. Open shaft guard #1. _____ Manually roll over power train. _____ Close guard. _____

---

c - This step permits OS switch bypass but retains manual ES shut-down via Governor Override from Power sytem and in Van.

_____ _____ _____ _____

Date: Test Staff:

Notes:

11. Activate Data Logger and Intercoms. _____ _____ _____ Log LOP fault _____ and SSP fault. _____

12. Hold Start switch on. _____ Log SSP fault. _____ Operate pump #2 to provide 150 psig oil. _____ Log no fault. _____ Observe Throttle open. _____ Log Throttle position. _____ Cycle Exciter switch. _____ Log US fault. _____

13. With Start switch still on, operate pump #3 to partly open Automatic Stop valve. _____ Rotation should start. _____ Watch Tachometer and drive fluid pressure. _____ _____ Watch oil pressure to bearings. _____ Release Start button slightly below LOP setpoint. _____ Observe Automatic Stop valve close slowly, stopping rotation. _____ Log LOP fault. _____ Log engineering data. See check list in Appendix.

14. With Start switch held on, operate pump #3 to partly open Automatic Stop valve. _____ _____ Observe rotation. _____ Monitor Tachometer and drive fluid pressure. Monitor oil pressure to bearings. Release Start button when oil pressure is above LOP setpoint. _____ Observe plant continue to run, throttled by Automatic Stop valve. _____ Log no fault. _____

15. Verify that lube oil reservoir temperature is above 60°F. Otherwise, wait until it is. _____ Then continue to open Automatic Stop valve to bring plant to standard operating speed. _____ Observe Governor take over. _____ Monitor RPM and adjust Governor as necessary. Open Automatic Stop valve slightly more. _____

16. Partly close Manual gate valve until plant begins to slow. _____ Open Automatic Stop valve fully, closing Manual gate valve in alternate increments if necessary to hold plant speed nearly constant. _____

_____ _____ _____ _____

Date: Test Staff:

Notes:

Transfer speed control to Manual gate valve with Governor adjusted for full Throttle. _____

17. Prop Automatic Stop valve about 7/8 open. _____

18. With Manual gate valve, adjust speed to standard operating RPM[d]. _____ Check operation of V_1 two or three times by adjusting sensitivity and adjust for normal plant operation. _____ Log V_1 fault and then no fault. _____ _____ Observe Automatic Stop valve close against the prop. _____ Turn Start switch to reset Stop relay. _____ Operate pump #3 to open Automatic Stop valve fully. _____ Check operation of V_2 two or three times by adjusting sensitivity and adjust for normal plant operation. _____ Log V_2 fault and then no fault. _____ _____ Observe Automatic Stop valve close against the prop. _____ Turn Start switch to reset Stop relay. _____ Operate pump #3 to open Automatic Stop valve fully. _____

19. Bypass OS switch and turn on meter. _____ _____ With Manual gate valve and tachometer, check OS trip RPM. _____ Note RPM at which trip occurs. _____ If trip does not occur before 11% overspeed, (see Rotor RPM table), set overspeed at 10%, (see table), and adjust OS trip to just open. _____ Then reduce RPM gradually to determine RPM at which OS trip closes. _____ Verify that OS trip opens on rising RPM. _____ Reduce speed to close OS switch and terminate bypass of OS switch. _____ During this step, continuously monitor RPM and press Emergency Stop if RPM exceeds 2400 RPM.

---

d - or adjust speed to a vibration node if one appeared during start-up.

_________ _________ _________ _________

Date: Test Staff:

Notes:

Rotor RPM				
Rotor Set	Male	Female		
			Overspeed	
			10%	11%
Low Speed	3000	2000	2200	2220
Medium Speed	4000	2667	2933	2960
High Speed	5000	3333	3667	3700

20. Adjust Manual gate valve so that speed cannot reach 10% overspeed (See Rotor RPM table) with Throttle wide open. ______ Then reduce speed to standard RPM with Governor and Throttle. ______

21. Open OHT circuit. ______ Log OHT fault. ______ Observe Automatic Stop valve close against the prop. ______ Reconnect OHT circuit. ______ Log no fault. ______ Turn Start switch to reset Stop relay. ______ Operate pump #3 to open Automatic Stop valve fully. ______ Remove prop. ______

22. Turn on Exciter. ______ Observe volt meter and frequency meter at Power Plant. ______ ______ Observe same in Van. ______ ______ Log voltage and frequency. ______ ______ Compare.

23. Adjust voltage at Power Plant. ______ Check remote voltage adjustment capability. ______

24. Adjust frequency to 60 Hz at Power Plant. ______ Check remote frequency adjustment capability. ______

25. Check operation of oil cooler fan. ______ Direction. ______

______ ______ ______ ______

Date: Test Staff:

Notes:

26. Check operation of ammeter at Power Plant. _____

27. Check Main Circuit Breaker remote trip operation. _____

28. Check greaser operation. _____ Set pressure at P_1 + 100 psi. _____

29. Using Manual gate valve, reduce RPM to monitor US trip speed. _____
Observe Automatic Stop valve close and Plant stop. _____ _____
Log US fault. _____

30. Press Emergency Stop button to open battery circuit. _____

31. Reactivate Governor Override relay for Stop circuit. _____ Remove meter and bypass circuit from Overspeed switch and replace leads on NC terminals. _____ _____

_____ _____ _____ _____

Date: Test Staff:

Notes:

ACCEPTANCE AND INTERFACE TESTING (Cont'd.)

E. DYNAMIC TEST PROCEDURE: SEMI-NORMAL START, RUN, STOP

1. Walk around Plant inspection. _____ Verify that Main Circuit Breaker is open. _____
2. Check battery. _____
3. Reset ES relay. _____
4. Place Exciter switch in US Bypass position. _____ Verify that oil cooler fan is in On position. _____
5. Activate Data Logger and Intercoms _____ _____ Log LOP fault _____ and SSP fault. _____ Log engineering data. _____
6. Open Manual gate valve fully. _____
7. Operate pump #1 to prime lube oil system. _____
8. Operate pump #2 to provide 150 psig oil. _____ LOP fault only. _____
9. Hold Start switch on. _____ Observe Throttle open. _____
10. While holding Start switch on, operate pump #3 to open Automatic Stop valve part way. _____ Watch Tachometer and driving pressure. _____ _____ Watch oil pressure to bearings. _____ Release Start switch when pressure exceeds LOP point ($\sim$12 psig). _____ Plant will continue to run, throttled by Start/Stop valve.
11. Verify that lube oil reservoir temperature is above 60°F. Otherwise, wait until it is. _____ Then continue. Open Automatic Stop valve to bring Plant to standard operating speed, shifting control to the Governor and Throttle. _____ Open Automatic Stop valve fully. _____ Monitor RPM and adjust Governor as necessary. _____

_________ _________ _________ _________

Date: Test Staff:

Notes:

K11

12 Turn on Exciter. _____ Watch Voltmeter and Frequency Meter at Power Plant. _____ _____ Look for Ammeter response. _____ Adjust frequencey to 60 Hz with Governor. _____ Adjust voltage to 480 V. _____

13. Check Oil Cooler air flow. _____

14. Cycle the Exciter to check the Governor response. _____ Monitor effect on frequency. _____

15. Operate plant three hours. _____ Log engineering data. _____ Refer to check-list in Appendix. Verify Greaser operation. _____

16. Press Stop button in Van. _____ Observe Automatic Stop valve slowly close and bring Plant to a stop. _____

17. Turn off Data Logger. _____ Turn off Intercoms. _____

18. Press ES button to open Battery circuit. _____

19. Shut off compressors. _____ Bleed off air. _____

20. Close Manual gate valve. _____

_____ _____ _____ _____

Date: Test Staff:

Notes:

K12

APPENDIX

CHECKLIST: ACCEPTANCE AND INTERFACE TESTING GUIDE

ITEM	PRESET	SIGNAL CHECK	STATIC TEST C	DYNAMIC TEST D	DYNAMIC TEST E
V_1	B1a	B4	C19	D18	
V_2	B1a	B4	C20	D18	
US	B1b	B4	C4,22	D5,28	
OHT	B1c	B4	C21	D21	
LOP	B1d	B4	C2,23	D11,13, 14	E5,10
SSP	B1e	B4	C7	D12	E5,8
OS	B1f	B4		D19	
Local S			C10		
Remote S		B4	C12		E16
Local ES			C15		
Remote ES		B4	C17		
S rate, valve	B1g		C10		
S rate, throttle	B1h		C12		
ES rate, valve	B1i		C15		
ES rate, throttle	B1j		C17		
Governor				D15	E11,14
Exciter				D22	E12
Voltage adjust, local				D23	E12
Voltage adjust, remote		B4		D23	
Frequency adjust, local				D24	E12
Frequency adjust, remote		B4		D24	
Ammeter, local				D26	
Oil Cooler fan				D25	E13
Greaser operation				D28	E15
Main Breaker trip remote		B4		D27	
Throttle Position		B4	C7	D12	E15
Throttle Bearing 1		B4	C7	D12	E15
" " 2		B4	C7	D12	E15
Expander Bearing Temp 1		B4	C7	D12	E15

APPENDIX (Cont'd.)

Expander Bearing Temp 2		B4	C7	D12	E15
" " " 3		B4	C7	D12	E15
" " " 4		B4	C7	D12	E15
" " " 5		B4	C7	D12	E15
" " " 6		B4	C7	D12	E15
Alternator Bearing Temp 1		B4	C7	D12	E15
" " " 2		B4	C7	D12	E15
" Winding " 1		B4	C7	D12	E15
" " " 2		B4	C7	D12	E15
" " " 3		B4	C7	D12	E15
" " " 4		B4	C7	D12	E15
" " " 5		B4	C7	D12	E15
" " " 6		B4	C7	D12	E15
Intercom		B4	C5	D11	E5
I. remote		B4		D12	E15
KW remote		B4		D12	E15

Revised 12/01/77
For Test of 12/04/77

D. DYNAMIC TEST PROCEDURE: MODIFIED START, RUN, STOP

1. Install circuitry with auxiliary switches to permit bypassing the OS switch. ______ (This is accomplished by placing a switched jumper across the OS relay output and an auxiliary switch in the OS switch output circuit. The switched jumper requires two switches in series, one at the start station and one at the backup RPM monitor station.)

   Place a meter across the OS switch terminals. _______ Leave all three switches in closed (on) position. _______

2. Activate the data logger and intercoms. _______

3. Check for SSP fault _______, LOP fault _______, US fault _______, OS no fault _______.

4. Open auxiliary switch in OS switch circuit (near OS switch). _______ Log OS fault. _______

5. Jumper US and OS in Van. _______ Log US no fault _______ and OS no fault _______.

6. Inspect the Power Plant, Van, and Cables for readiness. _______ _______ Verify that Main Circuit Breaker is open. _______ Set inhouse breaker off. _______ Record cumulative operating time. _______

7. Operate pump #1 to prime lube oil system. _______

Date: Test Staff:

Notes:

8. Open shaft guard #1. _______ Manually roll over power train. _______
Leave guard open to permit use of surface speed tachometer. _______

9. Check batteries. _______ Close battery switch. _______ Log SSP no fault. _______

10. Reset Emergency Stop relay to energize the safety shutdown circuit. _______

11. Verify that Exciter switch is in Underspeed Bypass position. _______

12. Verify that Automatic Stop and Manual 8" gate valves are closed. _______

13. Turn on compressors. _______ (Wear ear protection as necessary.)

14. Open Manual gate valve about 1/3. _______

15. Check nitrogen pressure. _______ Recharge if necessary. _______
Log engineering data. _______ See checklist in Appendix.

16. Hold Start switch on. _______ Observe Throttle open. _______

17. With Start switch still on, operate pump #3 to partly open Automatic Stop valve. _______ Rotation should start. _______ Watch Tachometer and drive fluid pressure. _______ _______ Watch oil pressure to bearings. _______ Release Start button slightly below LOP setpoint. _______ Observe Automatic Stop valve start to close slowly. Arrest with Start switch. _______ Log LOP fault. _______

18. With Start switch held on, operate pump #3 to partly open Automatic Stop valve. _______ Observe rotation. _______ Monitor Tachometer and drive fluid pressure. Monitor oil pressure to bearings. _______ Release Start button when oil pressure is above LOP setpoint. _______ Observe plant continue to run, throttled by Automatic Stop valve. _______ Log LOP no fault. _______ Observe US fault at plant. _______

Date: Test Staff:

Notes:

19. Verify that lube oil reservoir temperature is above 60°F. Otherwise, wait until it is. _______ Then continue to open Automatic Stop valve to bring plant to standard operating speed according to the following schedule.

   a. Male rotor 1500 RPM for 10 minutes (1/2 speed). Start time. _______ End time. _______

   b. Transfer control to governor at 1800 RPM. _______

   c. Adjust governor and automatic stop valve alternately to bring speed to 2500 RPM (50 Hz).

   d. Excite governor. _______ Bring speed to 2750 RPM. _______ (55 Hz)

   e. Turn on inhouse breaker. _______ Check operation of oil fan. _______

   f. With governor, slowly bring speed to 3000 RPM (60 Hz). _______ Run 10 minutes under governor control. Start time. _______ While running 10 minutes or more at normal speed, perform steps g through k.

   g. Adjust voltage at power plant to 480 V. _______ Check remote voltage adjustment capability. _______

   h. Adjust frequency to 60 Hz at Power Plant panel. _______ Check remote frequency adjustment capability. _______

   i. Check operation of ammeter at Power Plant. _______

   j. Check greaser operation. _______ Set pressure at P_1 to 100 psi. _______

   k. Calibrate tachometer with frequency meter at 60.0 Hz. Tachometer reading. _______ Calculate expected reading for 65.0 Hz and enter in step 24. _______ Calculate expected reading for 66.6 Hz and enter in step 25a.

Date: Test Staff:

Notes:

20. Close Stop metering valve for Automatic Stop valve. _______

21. Hold speed to standard operating RPM or adjust speed to a vibration node if one appeared during startup. Check operation of V_1 two or three times by adjusting sensitivity and adjust for normal plant operation. _______ Log V_1 fault and then no fault. _______ _______ Turn Start switch to reset Stop relay. _______ Check operation of V_2 two or three times by adjusting sensitivity and adjust for normal plant operation. _______ Log V_2 fault and then no fault. _______ Open Stop metering valve. _______

22. With speed adjusted to standard (60.0 Hz generator and 3000 RPM male rotor) cycle exciter to monitor speed change. _______ Note tachometer speed change. _______

23. Turn on voltmeter to monitor OS switch. _______

24. Increase speed to 65.0 Hz and check tachometer for correct reading. Theoretical = 3250. Calculated. _______ Observed. _______

25. If observed tachometer reading does not correlate well with the calculated value, step 23, leave exciter on and set OS switch at 65 Hz using frequency meter as speed reference. Adjust OS switch to open at high end of frequency meter. _______ Reduce speed with governor and note speed at which OS switch closes. _______ Increase speed until OS opens to verify setting. _______ Repeat as necessary.

25a. If observed tachometer reading does correlate well with the calculated value, step 23, turn off exciter and set OS switch using tachometer as speed reference. <u>During this step, continuously monitor RPM and trigger Emergency Stop if RPM exceeds 3450 RPM.</u> Adjust speed to 11% overspeed equal to 3330 RPM male rotor shown on the tachometer as _______ RPM calculated in step 19k.

Date: Test Staff:

Notes:

Set OS switch to just open at this speed. _______ Reduce speed with governor and note speed at which OS switch closes. _______ Increase speed until OS opens to verify setting. _______ Reduce speed to close switch _______ and repeat procedure as necessary.

26. Reduce speed to normal _______ and excite generator _______.

27. Terminate bypass of OS switch by first closing bypass switch _______ and then opening bypass jumper _______.

28. Remove US fault signal jumper _______ and OS fault signal jumper _______ in Van.

29. Using Manual gate valve, reduce RPM to monitor US trip speed. _______ Observe Automatic Stop valve start to close. _______ Log US fault. _______ Press ES at RPM = 1500 if possible and monitor Automatic Stop valve. _______ _______ Log engineering data at intervals until restart. _______

30. Open battery circuit. _______

31. Remove meter from Overspeed signal terminals. _______

32. Remove jumper from OS relay output. _______ Reconnect lead to OS switch output terminal. _______

33. Close Manual gate valve. _______

Date: Test Staff:

Notes:

E. DYNAMIC TEST PROCEDURE: SEMI-NORMAL START, RUN, STOP

1. Walk around Plant inspection. _______Verify that Main Circuit Breaker is open. _______Place Exciter switch in U.S. bypass position. _______ Set inhouse breaker off. _______
2. Manually roll over power train and re-install guard. _______
3. Log engineering data. _______
4. Operate pump #1 to prime lube oil system. _______
5. Close battery switch. _______
6. Reset ES relay. _______
7. Open manual gate valve about 1/3. _______
8. Check nitrogen pressure. _______ Recharge if necessary. _______
9. Hold Start switch on. _______ Observe throttle open. _______
10. While holding Start switch on, operate pump #3 to open Automatic Stop valve part way. _______Watch Tachometer and driving pressure. _______ _______Watch oil pressure to bearings. _______Release Start switch when pressure exceeds LOP point (~12 psig.). _______Plant will continue to run, throttled by Start/Stop valve.
11. Verify that lube oil reservoir temperature is above 60°F. Otherwise, wait until it is. _______Then continue. Open Automatic Stop valve to bring Plant to standard operating speed, shifting control to the Governor and Throttle. _______Open Automatic Stop valve fully. _______Monitor RPM and adjust Governor as necessary. _______

_______ _______ _______ _______

Date: Test Staff:

Notes:

12. Turn on Exciter. _______Watch Voltmeter and Frequency Meter at Power Plant. _______ _______Look for Ammeter response. _______Adjust frequency to 60 Hz with Governor. _______Adjust voltage to 480 V. _______

13. Check Oil Cooler air flow. _______

14. Cycle the Exciter to check the Governor response. _______Monitor effect on frequency. _______

15. Operate plant three hours. _______Log engineering data. _______Refer to check-list in Appendix. Verify Greaser operation. _______

16. Press Stop button in Van. _______Observe Automatic Stop valve slowly close and bring Plant to a stop. _______

17. Turn off Data Logger. _______Turn off Intercoms. _______

18. Press ES button to open Battery circuit. _______

19. Shut off compressors. _______Bleed off air. _______

20. Close Manual gate valve. _______

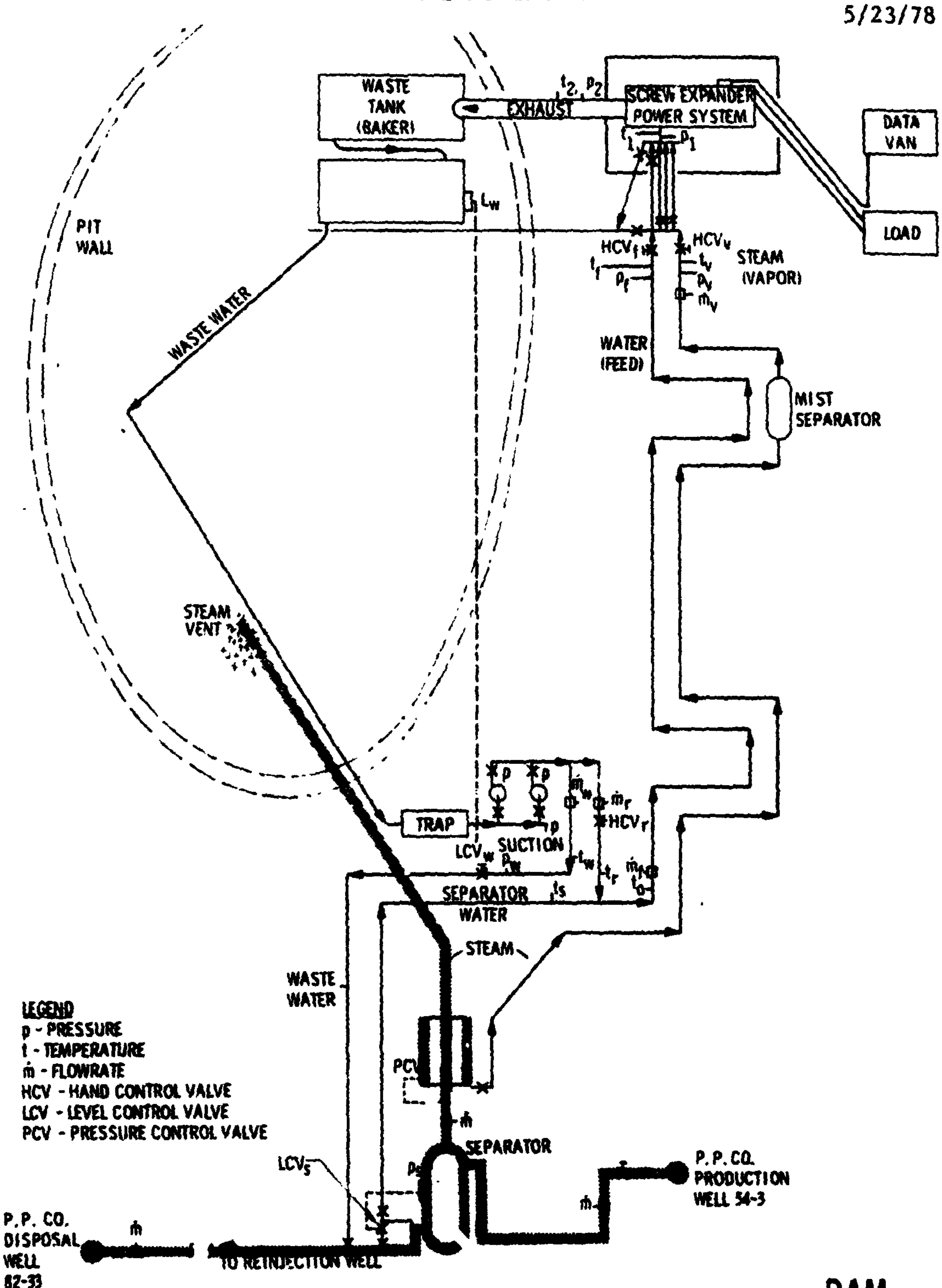
_________ _________ _________ _________

Date: Test Staff:

Notes:

SITE SCHEMATIC

As of 5/23/78



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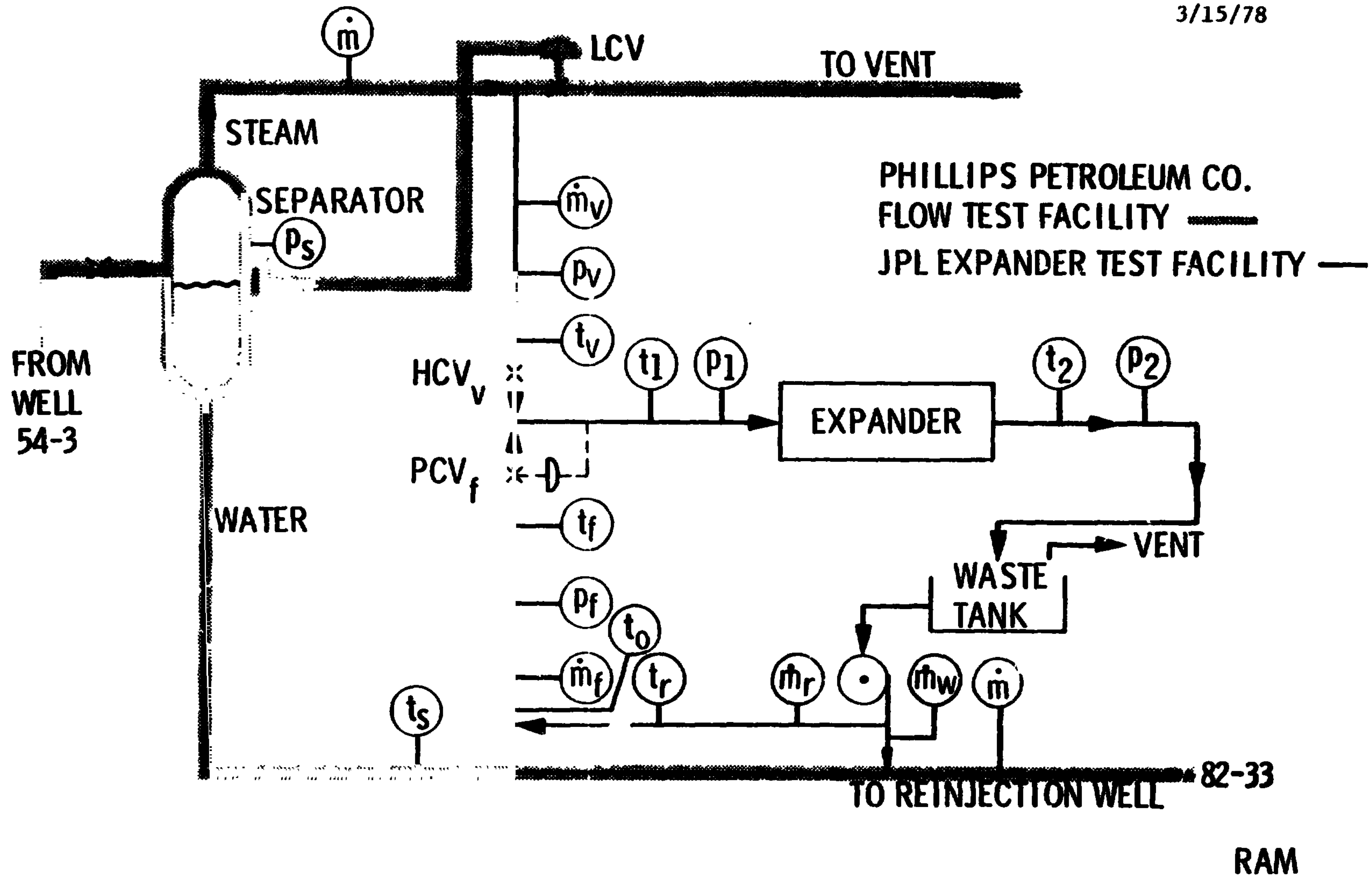
TEST FACILITY SCHEMATIC

As of
3/15/78



PROCESS NOMENCLATURE

t_r	recycle liquid temperature, ^oF
t_s	separator water supply temperature, ^oF
t_o	combined separator water supply and recycle temperature, ^oF
t_f	liquid feed temperature, ^oF
t_1	expander inlet temperature, ^oF
Q_1	expander inlet quality, %
p_1	expander inlet pressure, psia
p_f	liquid feed pressure, psia
T_{sup}	amount of superheat of the steam, ^oF
p_v	steam feed pressure, psia
p_s	separator pressure, psia
p_w	waste liquid pressure to flow control valve
$\dot{m}_w$	waste liquid flowrate, 1000 #/hr
$\dot{m}_r$	recycle liquid flowrate, 1000 #/hr
$\dot{m}_s$	liquid flowrate from separator, 1000 #/hr ($= m_f - m_r$)
$\dot{m}_f$	liquid flowrate to inlet mixing manifold, #/hr or 1000#/hr
$\dot{m}_v$	steam flowrate to inlet mixing manifold, #/hr or 1000 #/hr
L_s	liquid level in separator, in.
L_w	liquid level in waste tank, in.
"/h	rate of change of liquid level in waste tanks, in/hr
Trt %	linear throttle position as percent of fully open
kW	electrical output of alternator
freq	frequency of electrical output
eff %	engine efficiency of helical screw expander, actual shaft power/theoretical shaft power
Brg t	temperature of high speed rotor thrust bearing, ^oF

p_2	expander outlet pressure, psia
t_2	expander outlet temperature, ^{o}F
Q_2	expander outlet quality (steam fraction), %
t_v	steam feed temperature, ^{o}F

ORIGINAL PAGE IS
OF POOR QUALITY

		DATE								
		TIME								
	K. W.									
1	P. E.	P.S.I.G.								
2	APROX SEAL	AP'S								
3	MALE H P SEAL	P.								
4	FEMALE H P SEAL	P.								
5	MALE L P SEAL	P.								
6	FEMALE L P SEAL	P.								
7	MAIN OIL PUMP	P.								
8	OIL SUPPLY	P.								
9	OIL SUPPLY	T.								
10	GREASE	P.								
11	GEAR N° 1	T.								
12	GEAR N° 2	T.								
13	GEAR N° 3	T.								
14	GEAR N° 4	T.								
15	SAFETY N-2	P.								
16	SAFETY OIL	P.								
17	SHUTOFF GATE POSITION									
18	SEAL FILTER	Δ P								
19	OIL RESEVOIR LEVEL	IN.								
20	MAIN FILTER N° 1	Δ P								
21	MAIN FILTER N° 2	Δ P								
22	WATER PUMP	P.								
23	WATER FILTER	Δ P								
24	FLUSH WATER FLOW N° 1									
25	FLUSH WATER FLOW N° 2									
26	FLUSH WATER FLOW N° 3									
27	FLUSH WATER FLOW N° 4									
28	CENTRIFUGE WATER FLOW									
29	AIR COMPRESSOR	P.								
30	GREASE VEE BALL									
31	M-11 P. W.	P.S.I.G.								
32	RECIRCULATION FILTER	P.S.I.G.								
33	WATER RESEVOIR LEVEL	IN.								
34	BEFORE VEE BALL P_1	P.S.I.G.								
35	AFTER VEE BALL P_2	P.S.I.G.								
36	VEE BALL CONDITION				M					
37	INLET TEMPERATURE	T.								
38										